DETROIT/WAYNE COUNTY PORT AUTHORITY

PORT OF DETROIT DECARBONIZATION AND AIR QUALITY IMPROVEMENT PLAN

FINAL REPORT TO THE COMMUNITY

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ACKNOWLEDGEMENTS

The Detroit/Wayne County Port Authority (the "Port Authority") thanks the State of Michigan and Senator Stephanie Chang for providing the funding for the development of The Port of Detroit Decarbonization and Air Quality Improvement Plan and challenging the Port Authority to take bold action to reduce carbon emissions within the port region.

With this funding, the Port Authority was able to engage Tunley Environmental to provide expert technical consulting services in developing the baseline carbon calculations, conducting the scientific research into the proposed solutions, and leading the engagement with Port of Detroit terminal participants. Thank you, Tunley, for your work on this important project and we look forward to continued collaboration.

We also partnered with Southwest Detroit Environmental Vision ("SDEV"), who led community engagement efforts and helped the industrial businesses encompassing the Port of Detroit to understand the real impacts of port activity on the residents of Detroit and downriver communities. Through this partnership with SDEV, the Port Authority gained valuable community feedback from The Original United Citizens of Southwest Detroit ("OUCSD"). Both SDEV and OUCSD have been fighting for improved air quality and the health of residents in Detroit and neighboring communities of the Port of Detroit for decades.

Importantly, we want to thank each of the terminal operators, port businesses, and governmental entities who participated by voluntarily sharing their emissions data, provided guidance on operations, and recommended practical solutions that could form the basis of an action plan. We could not have performed this study without such engaged involvement. We also look forward to continued collaboration as we work to decarbonize the Port of Detroit together.

Lastly, we thank the support of the Detroit/Wayne County Port Authority Board of Directors, who approved our vision and the contracts necessary to carry out this work.

The Detroit/Wayne County Port Authority would like to acknowledge that Detroit and SE Michigan is Anishinabewaki ᐊᓂᔑᓈᐯ·ᐊᑭ, Mississauga, Peoria, Meškwahki·aša·hina (Fox), Myaamia and Bodéwadmiakiwen (Potawatomi) ancestral land. We acknowledge the land to honor its people, show respect, acknowledge our history of conquest, and resist the erasing of the First Nations.

EXECUTIVE SUMMARY

The Detroit/Wayne County Port Authority takes seriously its responsibility to limit climate change from carbon emissions and to improve air quality for the overall health of residents, workers, and visitors to the 1,000+ acres along the Detroit and Rouge Rivers, collectively known as the Port of Detroit. This report is the first step in fulfilling that responsibility to reduce the environmental impact of maritime activity, which is currently at 3% of global emissions and increasing.

Through a year-long effort of engagement with terminal operators, tugboat companies, and other essential port support operators, we have developed a reliable estimate of the greenhouse gases emanating as a result of port operations, totaling **30,269 metric tons CO_2e per year**. This is equivalent to burning 166 railcars of coal, and enough CO_2 by volume to fill the Detroit Lions Professional Football Team's stadium, Ford Field nearly 44 times. We have also engaged with those who live, work, and travel through the port to hear the call to action for cleaner air, reduced sound, vibrations, and danger in neighborhood streets caused by trucks that haul cargo from the port. Finally, we have studied what other ports have done on their journey toward reducing emissions and improving air quality and have collected best practices to perform the baseline carbon assessment for the Port of Detroit. Additionally, a series of actionable steps have been put in place to reduce port-related emissions, immediately and in a sustained way, to reach net zero by 2040. Emissions reduction in the near term will be achieved through the use of biodiesel, and electrification where possible, followed by other low-carbon fuels as they become more cost competitive.

This report is not an end, but a beginning in the Port of Detroit's long road to becoming the 'Green Port of Detroit' and reducing carbon emissions to net zero by the year 2040. In doing so, we hope to develop a port that is economically viable while not sacrificing the health of the planet and its people.

This report explores the history of the port region and the peoples who thrived along the banks of this rich area. This vital waterway and the proximity of raw materials was the foundation for Detroit to become the greatest industrial city of the early 20th century, and the automobile capital of the world. That progress, however, came at a cost – in the form of contribution to climate change, negative health impacts for our workers and residents, and building a trajectory of carbon emissions from our industrial production that we are now facing on a global basis.

Below is a summary of our findings and the preliminary plan for achieving net zero by the year 2040. It will take all of us to get there, so please join in.

Call To Action

The urgency of climate change is clear. It is impacting our water levels, causing dramatic weather pattern shifts, sea level rise, and affecting our ability to grow food. The goal of limiting the rise in global temperatures to no more than 1.5 degrees Celsius [1] is in jeopardy if we do not change course and begin reducing our usage of carbon-emitting fossil fuels like oil, natural gas, and diesel fuels immediately. There are technologies to make this happen and resources are now flowing from the federal and state government to implement both long and short term changes in the maritime industry. With the collective willingness to change, we can each participate in limiting our contribution to climate change.

This plan is a call to action for all of those who live, work, and are active in the area known as the Port of Detroit. Each of us can get involved by advocating that our businesses, governments, organizations, and individuals act now. This plan is an opportunity to rebuild the Port of Detroit in a way that respects nature, values human life, and prioritizes the health of the environment.

Join in the effort. We cannot do it without you.

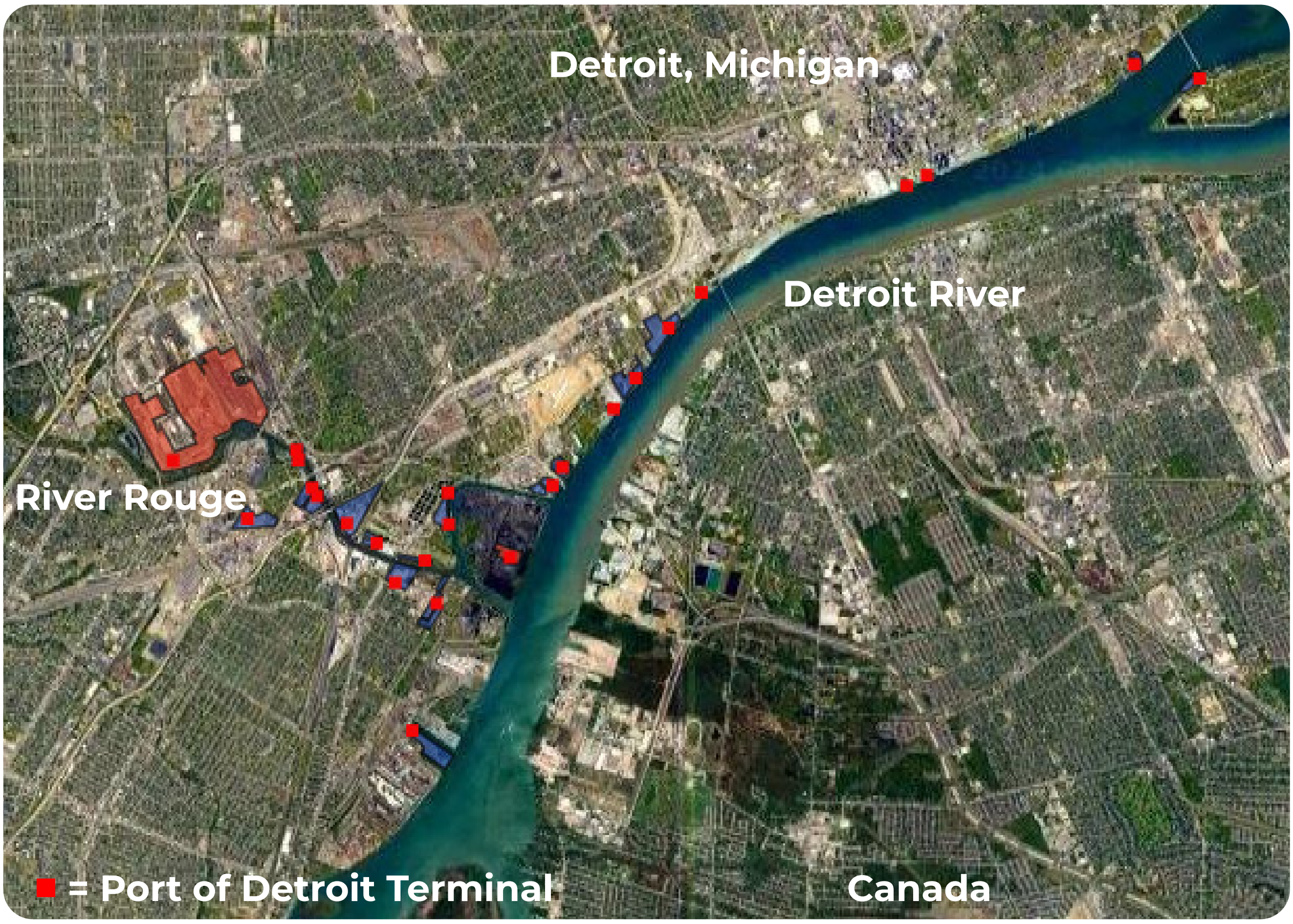


Figure 1: *A satellite map showing the Detroit River, with the locations of the Port of Detroit Terminals in red.*

INTRODUCTION TO THE DETROIT/ WAYNE COUNTY PORT AUTHORITY

The Port Authority is a governmental entity, created under the authority of the Hertel-Law Stopczynski Act of 1978 (MCL 120.101, et seq.) and by agreement between the City of Detroit and Wayne County, signed 45 years ago to promote maritime trade and developing port facilities within the Port of Detroit. The Port Authority has the power to, among other things, perform studies and promote commerce, health, and recreation within the Port of Detroit. Development of a Decarbonization and Air Quality Improvement Plan (the “Plan”) for the Port of Detroit will contribute to port-wide sustainability efforts and improve the health of those who live, work, and recreate within the region.

The Port Authority owns a 34-acre general cargo dock, located at 4,461 Jefferson Avenue in Detroit, Michigan, which is a part of the larger Port of Detroit. The dock typically receives steel slabs and coils, heavy equipment, and project cargo. In recent years, the terminal has received between 200,000 and 500,000 U.S. tons of cargo annually. No products are exported from the general cargo dock. The Port Authority also owns and operates a public dock for passenger vessels, including cruise ships that traverse the Great Lakes. The cruise ship industry within the Great Lakes has been growing rapidly; and Detroit is one of the most popular destinations, serving 62 ships and over 15,000 passengers in 2022.

The Detroit/Wayne County Port Authority is the industry leader for the Port of Detroit terminals, acting as promoter of maritime trade, and economic development. The Port Authority’s role includes widening the Port’s profile, both nationally and internationally, acting as a local authority for grant applications, for everything from sustainability to infrastructure developments, and bringing in more trade to the region. Combined, this brings jobs and prosperity to the region.

According to an economic impact study released in 2023, approximately 8 million tons of cargo passes through the Port of Detroit annually, producing over $900 million in local economic activity, including over $529 million in local wages. The Port is also responsible for over $52 million in local taxes collected [2]. The approximate land area covered by the Port of Detroit that remains in use is over 1,000 acres spread out along the Detroit and Rouge Rivers. The types of cargo received within the Port of Detroit include bulk materials (cement, salt, road-building materials), liquid products (petroleum, chemicals, and other fuels), steel, coils, heavy equipment, and other cargo. This plan covers 24 separate assessments of private terminals that import and export cargo, the Port Authority, smaller vessels, and government entities with a presence on the water.

THE DECARBONIZATION AND AIR QUALITY IMPROVEMENT PLAN

The Port of Detroit Decarbonization and Air Quality Improvement Project was initiated by the Port Authority in the Spring of 2023, with funding provided by the State of Michigan. Both climate change and air quality concerns were strong motivators for the project. Detroit has experienced increased levels of flooding, extreme weather conditions, and poor air quality as a result of climate change. With regards to air quality, a recent article by Harvard Medical School highlights Southwest Detroit as having some of the worst air quality in the United States [3], with corresponding high rates of asthma, cancer, and respiratory illness. Both climate and air quality challenges can be addressed simultaneously by replacing fossil fuels for cleaner fuels, reducing both greenhouse gases and air quality pollutants. Cleaner fuels have advantages to businesses seeking to enhance their reputation and market share, as consumers seek to purchase from businesses with strong environmental credentials.

A request for proposal was released and the application process ensued, with Tunley Environmental being the successful bidder for the consultancy work, and Southwest Detroit Environmental Vision leading the community engagement for the decarbonization project.

The overarching goal for the project is to assess the greenhouse gas (GHG) emissions for the Port and build a pathway to become net zero by 2040. Further, the Plan also seeks to reduce pollutants such as nitrous oxides, sulfur oxides, particulate matter, excessive noise, vibrations, and light pollution, all of which contribute to the poor air quality and negative health outcomes in Southwest Detroit and downriver communities. The vision of the Plan is to minimize the negative impact of port operations on both people and the planet while encouraging green jobs and economic prosperity within the region.

The project calculates the emissions of each terminal operating within the Port of Detroit for shipping, goods handling, and drayage (local trucking/rail), with the results updated on an ongoing basis. The results from this study are published on the Port Authority's website as both a report, and as an interactive map for any member of the public to view. Businesses that have not collaborated with this project will have their emissions estimated using publicly available data. The Port Authority encourages these private businesses to sign up for Green Marine, an organization that provides the framework for continuous improvement of environmental standards for the shipping industry. This project will be carried forward by two working groups: the Low Carbon Port Committee (consisting of the businesses in the Port of Detroit) and the Port of Detroit's Decarbonization Plan and Air Quality Improvement Plan Advisory Board (made up of community members, governmental officials, and local experts). These groups will collaboratively plan initiatives, seek funding, and provide accountability for reaching the Plan's goals.

THE HISTORY OF THE PORT REGION

Detroit's rich history is deeply intertwined with the experiences of Indigenous communities, whose land was initially inhabited and cultivated long before European settlers arrived. Michigan was home to the Ojibwa, Ottawa, and Potawatomi tribes. They formed an alliance called the Anishinaabeg, or The People of Three Fires. These tribes frequently worked together to maintain peace and trade. They originated from the same tribe, spoke similar languages, and had similar cultures and traditions [4]. Of these three, the Ottawa people lived along Lake Huron, slightly north of current-day Detroit [5] and likely lived in the Detroit region as well. The Huron tribe was thought to inhabit Southeast Michigan and what is present-day Detroit.

These tribes would hunt, fish, build canoes and plant and harvest crops in the region. Fort Wayne, located along the Detroit River, is the site of an important burial ground for the Indigenous community. These three tribes would meet up each year, likely in Detroit, as the location along the river allowed for access by water for all members of the Three Fires [4]. It is essential to acknowledge the foundational presence and contributions of these Indigenous peoples to the region, as they were the original inhabitants of what is current-day Detroit.

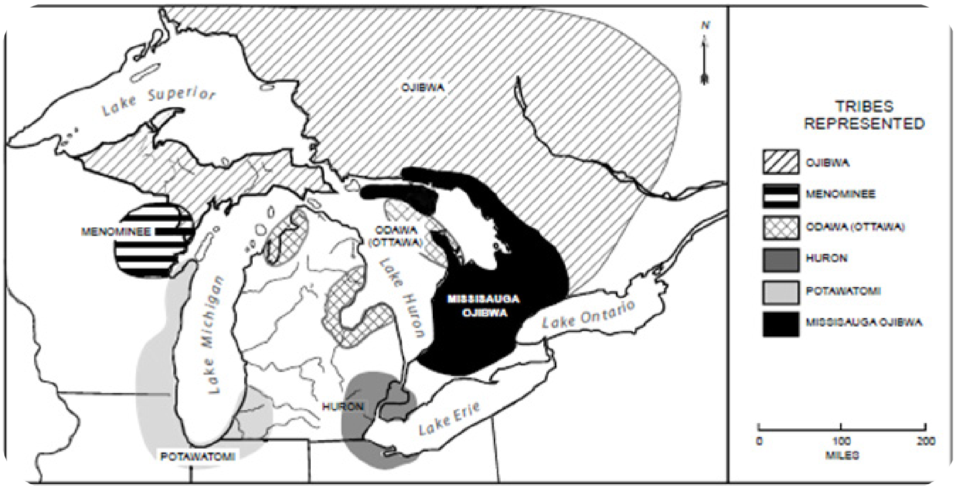


Figure 2: *The general regions Indigenous tribes inhabited in the region [5].*

Much sickness was brought to these tribes by the presence of European settlers and over time, the land that historically belonged to these tribes was taken or bought and inhabited by French and British settlers. The European settlers brought with them conflict and diseases that reduced the native population, and treaties that limited native land control ultimately led to the decline of indigenous peoples in the State of Michigan [4].

Beginning in the early days under French control, Detroit established itself as a hub for agriculture and fur trading. British settlers moved further west and sought control over this region as well. Over the years, both British and French nations fought for control of the region by partnering with Native tribes, with the land trading hands multiple times between the 1600s and 1800s, until the United States officially gained control over the region in 1796 when the British military leaders surrendered. Detroit was a coveted location as it served as a vital trade route into the heart of North America.

The 1800s marked a significant turning point with the industrialization boom in America, with Detroit entering as a key manufacturing city for goods including steelmaking for railcars, tobacco, boiler factories, and brickyards, amongst many industries. Later, the automotive industry, led by Henry Ford, whose vision for an entirely self-sufficient facility brought about the automobile's success. Detroit's location on the water, with easy access to multiple modes of transportation — highways, railways, and especially the waterways — was essential to its industrial growth, attracting workers from far and wide with promises of high wages and opportunities.

The maritime industry is essential to Detroit's success for many reasons, but primarily, it enabled large quantities of raw materials to be brought in, at low cost, to be used by manufacturing. The first steam vessel was built in 1818, followed by the first steam barge in 1848, which allowed for a significant increase in quantity of shipped goods. Detroit connected much of the Midwest to the Great Lakes, as roads and railways enabled the transport of goods throughout the region. Prior to the automotive industry, Detroit was a leader in many other types of manufacturing, including shipbuilding and stove-making [6].

Detroit became known by the rest of the world as the Motor City. Henry Ford founded the Ford Motor Company in 1903, and a few years later introduced the Model T, which became the car that changed the direction of the automotive industry. The Highland Park plant was built in 1913; here he developed the assembly line and increased the wage to $5 a day, an unheard-of amount at that time [7].

Figure 3: *Ford Rouge Complex [8].*

In 1928, the Ford River Rouge Complex was completed. This facility produced every part required to build a whole car, from the raw materials to assembling the final products. Ford employed engineers to widen the River Rouge and cut a new channel (creating Zug Island) in order for large freight ships carrying iron ore and coal to reach his facility [7]. This River Rouge Complex helped Ford rise above the competition and solidified Detroit as the car manufacturing capital of the world.

However, alongside the growth of Detroit came racial segregation and inequality. Communities of color were often relegated to less desirable neighborhoods, with industrial sites and highways often moving into these communities' backyards. This systemic injustice not only perpetuated social divides but also inflicted tangible health burdens, with residents disproportionately exposed to pollution and its associated health risks.

In recent years, there has been a growing awareness of the need to address environmental and public health concerns, and transition away from heavy pollution sources of energy, such as coal. Efforts to mitigate pollution and promote sustainability have led to the closure of some industrial entities, signaling a shift toward a cleaner, more equitable future for Detroit and its inhabitants. Yet, challenges persist, particularly in areas like the port region, where heavy industries continue to operate, and are essential to the state's economy. The Port of Detroit seeks to balance economic interests and environmental stewardship by envisioning a future port that is green and beneficial to the surrounding community, rather than a negative influence on health and well-being.

FREE TRADE
Port of Detroit is one of the largest Free Trade Zones in the United States.

HEAVY LIFTER
Port of Detroit handles approximately 8,177,000 tons of bulk cargo every year.

ECONOMIC GENERATOR
Port of Detroit generates 16,000 jobs and $1.04 billion in economic activity.

OCEAN GOERS
Port of Detroit handles Ocean Cargo ships and Great Lakes ships.

Figure 4: *The Detroit/Wayne County Port Authority Building.*

CLIMATE CHANGE

Climate change refers to long-term alterations in Earth's climate patterns. While natural processes have historically driven climate fluctuations, the current trajectory of change is unequivocally attributed to human activities [9]. The primary culprits are the emissions of greenhouse gases, such as carbon dioxide and methane, resulting from the combustion of fossil fuels, deforestation, and industrial processes. These emissions enhance the natural greenhouse effect, trapping more heat within the Earth's atmosphere and leading to a discernible warming trend.

The impact of a warming climate, even by a rise of 1 degree Celsius leads to more frequent and more intense natural disasters, such as the recent Canadian Wildfires of 2023 [10], flooding in Southwest Detroit in 2021, and the Michigan heatwave in 2020 [11] [12], with record-breaking temperatures across the state. These events are known to disproportionately affect vulnerable, low-income neighborhoods – those who contribute the least towards climate change are impacted the most.

Figure 5: *Images from flooding in Detroit in 2021, evidence of the impact of climate change on the community.*

The impacts of climate change extend to ecosystems, biodiversity, and food security [13]. Changes in temperature and precipitation patterns disrupt habitats and lead to the decline of native species. For instance, algal blooms are likely to become more common in both Lake Erie and Lake Michigan, and various tree species in the upper peninsula are likely to decline in population, including paper birch, quaking aspen balsam fir, and black spruce [14]. Globally, coral reefs, polar bears, and migratory species are grappling with the consequences of altered climates, emphasizing the urgent need for concerted conservation efforts [15].

The Paris Agreement, established in 2015, serves as a global initiative where nations unite to address the challenges posed by climate change. Those who signed the agreement, including the United States, commit to limiting the temperature rise to well below 2 degrees Celsius above pre-industrial levels, with a more aspirational goal of 1.5 degrees Celsius [16]. This would limit the negative effects of climate change as much as possible considering 'tipping points' (such as irreversible glacial retreat) within our earth's systems. However, the evidence is clear that we are already observing the negative consequences of climate change, and these will intensify with every additional fraction of a degree of warming, a trajectory we are currently on.

These targets are meticulously informed by the scientific assessments conducted by the Intergovernmental Panel on Climate Change (IPCC), a global consortium of leading climate scientists and policymakers. The urgent call for mitigation efforts echoes through the IPCC's assessments, emphasizing the critical need to curb greenhouse gas emissions and avert catastrophic consequences [17].

AIR QUALITY'S IMPACT ON HEALTH

The Port of Detroit is more than an industrial area along the Detroit and Rouge Rivers. It cuts across several municipal boundaries and is often referred to as Southwest Detroit or Downriver, and includes parts of Detroit, River Rouge, Ecorse, Dearborn, Wyandotte, Trenton, and Grosse Ile. This area is home to a diverse array of communities, ethnicities, and cultures that have settled near the jobs and opportunities available in the Port region. In addition to industrial activity, the area is a logistics hub, with many highways, railways, and soon to be two international bridges, serving as the thruway for tens of thousands of truck trips every day. The concentration of industrial and transportation activity in this region, combined with relaxed industry health and safety regulations over the years, has resulted in some of the poorest air quality in the nation [18].

The U.S. Environmental Protection Agency (EPA) defines key pollutants as those with known negative impacts on human health, including those that are the result of burning fossil fuels, including:

- Particulate matter ($PM_{2.5}$)
- Sulfur oxides (SO_x)
- Nitrous oxides (NO_x)

Residential areas in and near the Port of Detroit are directly exposed to these sources of pollution, leading to increased levels of exposure to pollutants that are often higher than recommended as safe for human health [18]. The cumulative risk map in the tri-county area below shows the combination of high particulate matter emissions combined with population vulnerability for much of Detroit.

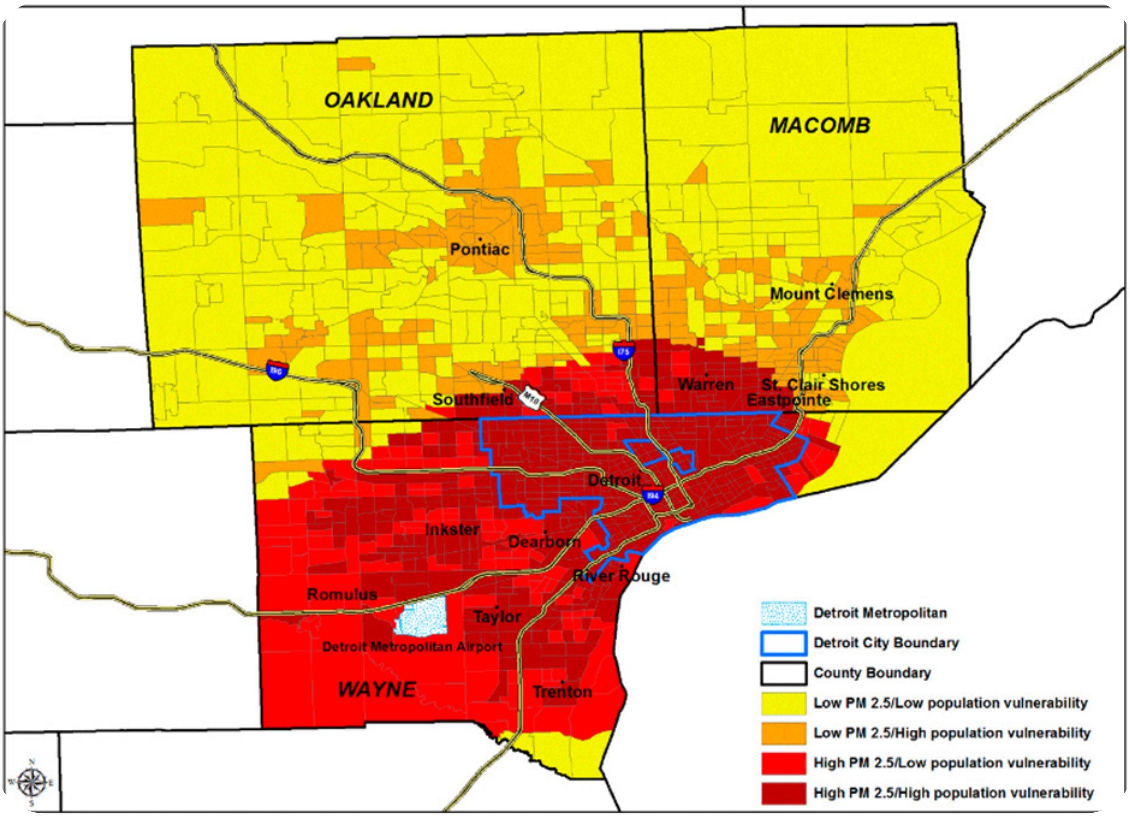


Figure 6: *This map displays the high levels of particulate matter pollution combined with population vulnerability in Detroit due to high levels of industrial activity in the region.*

Through better understanding, changing working practices, and reducing fossil fuel consumption at the port terminals, air quality will improve. Implementing carbon and air pollution reduction strategies can have far-reaching positive impacts on those who live and work in Detroit.

The Port of Detroit's Role in Air Pollution

A portion of the emissions in Detroit are a result of the port and port-related activities. The primary source of port emissions comes from shipping, goods handling, drayage, staff commuting, and co-located industrial activity. Of all these emissions sources within the scope of this project, trucking was found to have the highest impact, as trucks drive through communities, and are the closest emission source to homes, schools and places of work and leisure. This project aims to recommend terminals operating in the port region to reduce their environmental impact by changing their fuel source and investing in clean technologies. This includes those that are not directly covered by this study, including trucking firms and non-port industrial facilities. The Port Authority acknowledges the impact the port region and port-related activity has on the community and is seeking to take responsibility for these emissions by the development of this decarbonization plan.

Figure 7: *Zug Island, one of the most polluted sites in the U.S. Currently, this facility is owned by DTE and is used to make coke, an input for steel making.*

SOUTHWEST DETROIT ENVIRONMENTAL VISION: COMMUNITY ENGAGEMENT

Air Quality In The Region

In 2022, the Asthma and Allergy Foundation's Asthma Capitals Report listed Detroit as the worst city in the U.S. to live in if a person suffered from a breathing ailment [19]. The air pollution created by industrial, energy production, and mobile sources (highway/port) creates serious environmental justice concerns for directly affected residents. The EPA's EJSCREEN displays the pollution present in the community with the National Air Toxics Assessment (NATA) diesel particulate matter (PM) rating in the highest 10% in Michigan, well above the 90th percentile (when compared to the rest of Michigan). The PM2.5 was measured in the highest 20% compared to the rest of the U.S. with poor air quality. In addition, the number of under or uninsured residents (19% of Detroiters under 65 years old have no health insurance) coupled with a lack of transportation and other socio-economic barriers, residents of Detroit face significant risk from air pollution exposure [20], [21]. Detroiters experience higher asthma fatality rates than the rest of the state, as well as other health impacts, including high blood pressure, cancers, and stroke risk caused by industry and transportation related emissions. This public health impact extended to higher-than-average cases of severe COVID-19 and mortality rates during the height of the pandemic in Detroit. The Detroit/Wayne County Port Authority Decarbonization and Air Quality Improvement Project was developed to help benchmark and plan to reduce port-related emissions contributing to air pollution, specifically in the frontline communities of Southwest Detroit, South Dearborn, and the Downriver Communities. This includes the 48217 zip code, which is considered the most polluted zip code in Michigan. This directly impacted region provides economic benefits to the entire state and nation, and is home to unique natural amenities and a vibrant population deserving of a high quality of life.

A History of Environmental Work In The Community

Detroit, River Rouge, Ecorse, and South Dearborn, which are socio-economically distressed areas, bear a disproportionate environmental and public health burden as the host communities for heavy industry, utilities, and highway infrastructure. Southwest Detroit is home to six of the top ten most polluted zip codes in the state due to: heavy industry with major steel forging mills, a petroleum refinery, several cement businesses, an average of 10,000 trucks crossing the International Ambassador Bridge daily, a second bridge opening Fall of 2025, and the Detroit Intermodal Freight Terminal which hosts the CSX and Norfolk Southern railyards. The City of Detroit residents have a long history of engaging with industry and making substantial gains in policies like the Detroit Waterbody Protection Ordinance, created in response to the 2021 dock collapse of uranium-contaminated land and the closing of the Detroit Incinerator in 2019 due to the action of a consortium of Detroit organizations. In 2007, SDEV led efforts in a community listening project supported by a U.S. EPA CARE Level I & II cooperative agreement. In 2008, residents banded together to create the Southwest Detroit Community Benefits Coalition to address the development of the Gordie Howe Bridge and its impact on residents. The 2019 Baseline for **Healthy Impacts on the Gordie Howe Bridge Study** outlines the detrimental effects of industry on the health of residents and are outlined in Delray's organizing history report [22].

It was these wise community voices that the Detroit/Wayne County Port Authority sought to include as part of the Decarbonization Plan feedback. This plan seeks to involve, continuously inform, and elevate the voices of directly affected residents, without whose commitment to Detroit, Detroit's resilience would not be possible.

Upon initiation of the project, the Port Authority expressed a goal to be available and welcoming to residents through community meetings, presented findings, and has worked to collect feedback and ideas from those most directly impacted by port activities. Resident leaders focused on environmental matters have a long-standing history and relationship with the community institutions, schools, and industry that surround them, and have worked diligently to shape their communities and policies. They continue to hope for and work towards a future with clean air and water for the region.

The Decarbonization Plan and Community Engagement

Project Introduction, May 11, 2023: The decarbonization team held a community meeting at the Kemeny Recreation Center with residents of 48217, Ecorse, and River Rouge to open a dialogue to register project concerns, and allow the decarbonization team to hear about the lived experience of community members. Approximately sixty residents and community stakeholders attended. The team shared the project timeframe and goals, and surveyed resident experts on concerns, hopes, and fears for the decarbonization project. Residents are the eyes and ears of a larger ecosystem that creates a feedback loop on industry, neighborhoods, policies, and community health.

Figure 8: *The first community meeting to introduce the Port of Detroit Decarbonization project to the community and ask for feedback.*

Project Update Meeting, January 25, 2024: The project's second meeting took place at the City of Detroit's Detroit Police Department's 4th Precinct community room. Residents expressed a curiosity to learn more about the projects' advancement and similar projects in the area that the Port of Detroit and industry partners are engaged in. As our team and partner, Indigenous Energy, shared project learnings with residents, biodiesel's ability to immediately reduce emissions excited residents. Theresa Landrum, a long-time resident, and environmental justice leader, stated, "Why don't we have this now? How do we get the trucks on our roads to use biodiesel?" Support from residents to move forward in implementation provides momentum for the decarbonization plan to pursue reduction strategies and seek support from others in the region, including government officials.

Figure 9: *A community update meeting to present initial findings of the Port of Detroit Decarbonization project to the community and ask for feedback mid-way through.*

Project Findings and Next Steps, April 8, 2024: The team revealed the results of the year-long study to determine the total carbon emissions generated by the Port of Detroit. This event, held at Kemeny Recreation Center, shared the baseline emissions for the port region, with a group of Detroit residents and environmental organizations. This information is publicly available on the **Port Authority's website** as an interactive map that displays the terminals' location and individual baseline emissions. Additionally, an executive summary report details the emissions sources, as well as the strategies to reduce fossil fuel usage in the port was published. From here, implementation of these decarbonization strategies begins, with the Port of Detroit striving to reduce emissions to reach net zero by 2040.

Figure 10: *The final community meeting to present the Port of Detroit Decarbonization results to the community and discuss next steps for the implementation of the Plan.*

Voices of the Community

The community have expressed their frustration in the permitting process and felt ignored by the EPA and Michigan Department of Environment, Great Lakes, and Energy (EGLE). Due to their proximity, residents have repeatedly expressed a desire to be engaged in industry matters and decision making. Residents have noted the importance of regular community meetings to voice concerns to industry leaders and City of Detroit elected officials. Overall, residents want to have more opportunities to be directly informed about industrial activity and be involved in the decision-making process within their community.

The Port Authority taking measures to reduce GHG emissions has been welcomed by residents. Residents expressed real excitement about how biodiesel (a soybean oil derived diesel fuel alternative that can lower lifetime carbon emissions up to 74% [23]) could reduce emissions immediately in the area. The Port Authority and the decarbonization team are committed to continue to build lasting and meaningful partnerships with these directly affected communities. Additionally, the Port Authority seeks to connect residents to the industries decision makers to foster relationships between the Port and the community. This will be accomplished through the Port of Detroit's Decarbonization and Air Quality Improvement Plan Advisory Board; interested community members will be able to join to keep the port accountable for implementing the plan.

METHODOLOGY OF THE DECARBONIZATION PLAN

The maritime industry accounts for 3% of worldwide emissions [24]. There is an increasing movement towards lowering carbon emissions in this sector, as shipping is the largest goods transport sector by tonnage, and volumes are increasing. To reduce the carbon footprint of an organization, the first step is to identify and quantify emissions sources. There are three classifications of emissions from the Greenhouse Gas Protocol: Scopes 1, 2, and 3.

Scope 1: Direct emissions, predominantly due to burning fossil fuels within owned or operated equipment. This includes ships or equipment owned and operated by an organization that burns fuel on-site to power their operations.

Scope 2: Indirect emissions from owned or operated equipment, largely, where the emissions occur off-site due to operation. Typically, these are emissions associated with electricity use and the required energy generation activity.

Scope 3: Everything else. These come from embodied carbon of goods, staff/customer commuting, transportation of third party owned vehicles, among many other upstream/downstream emission sources.

As the Port of Detroit is made up of primarily independently operated private businesses or terminals, a report on traditionally defined Scopes 1 and 2 would be limited to the Port Authority. Their leased property operated by Nicholson Terminal and Dock, and the remaining businesses operating on the water to fall within Scope 3 emissions. To include these and assign greater responsibility is with the individual terminals to implement carbon reduction strategies, each terminal was considered its own entity, each with a separate and unique emission reduction plan issued by Tunley Environmental.

A number of ports across North America have developed their own decarbonization plans, including the Ports of Los Angeles, Houston, Vancouver and Seattle, among others. As each port differs greatly in their operational control, size, cargo make-up and tonnages, the strategies for port decarbonization vary. For ports that have a landlord structure, where the port authority owns the land, and has tenants, a more traditional carbon emissions inventory with Scopes 1, 2, and 3 more clearly defined can be accomplished. However, most only have targets for Scopes 1 and 2, with few ports addressing Scope 3. Other U.S. ports have drawn physical boundaries to declare the emissions they are directly responsible for as a result of fuel burnt from ships, trucks, and rail calling on their port; California based ports and the Port of Vancouver are key examples. Not all ports use the same definition of Scopes 1, 2, and 3. However, the assessment for the Port of Detroit follows the GHG Protocol, the EPA Port Emissions Inventory Guidance, and International Standards from ISO 14060 family. This plan uses a physical emissions boundary, shown in Figure 11.

Port of Detroit Emissions Boundary

The scope of emissions includes a physically defined boundary along the Detroit River and River Rouge. This defines the distance of shipping activity within these 28 miles for vessels calling on the businesses in this port. The movement of goods on and off the ship and on-site at the terminals is considered as goods handling. Additionally, a boundary of a 15-mile radius for drayage, including truck or train movement of goods from port facilities to an end user. This boundary only includes port-related operations (with industrial operations excluded to focus only on port-related movement of goods).

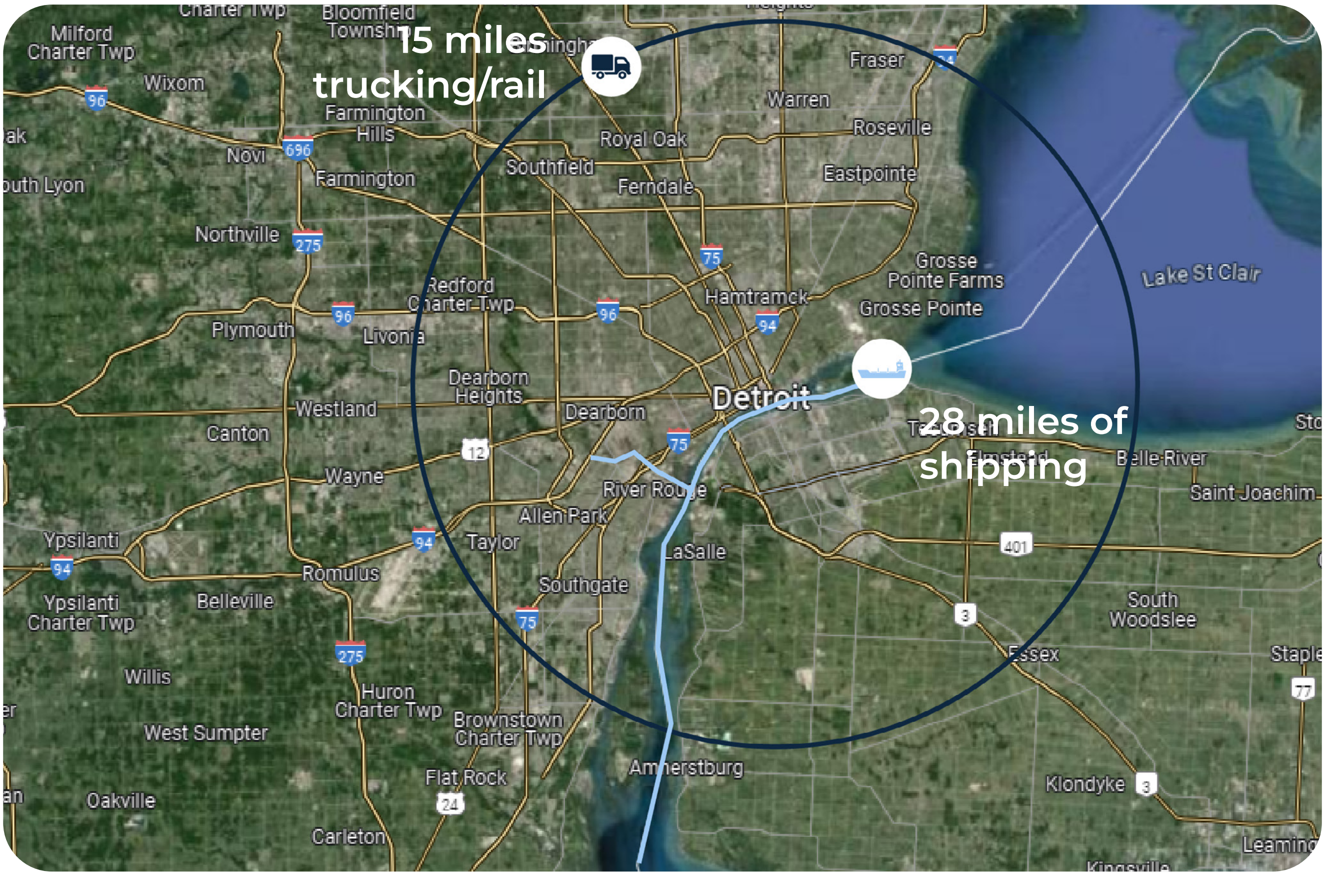


Figure 11: *Geographical emission inventory boundary diagram for ship, truck, and rail movements within the Port of Detroit region. Goods handling and local ship traffic along the river are also included.*

The Port Authority owns and operates a public dock, primarily serving cruise ships, along with a facility that hosts over 100 events each year. For purposes of this study, the Port Authority has undergone a thorough assessment, demonstrating leadership by a greater understanding of Scope 3 emissions for the cruise ship and catering operations, in addition to its administrative office space. The Port Authority is a member of the Green Marine organization as of 2023, seeking to lead by example as it pursues continuous environmental improvements while encouraging other terminals in the Port of Detroit to also pursue this certification.

Project Engagement

Key to the success of this project has been to build a cohesive network of stakeholders, including the private terminals, government entities, and support services within the port region. Consequently, the project has seen strong support, with 21 out of the 24 maritime related entities voluntarily providing sensitive operational data to the project. The data provided was independently assessed and cross-referenced with publicly available reports. There were three terminals who have not yet volunteered information for the Decarbonization Plan: DTE Zug Island Operations (EES Coke Battery), Cleveland Cliffs, and Marine Pollution Control. For these organizations, emissions were estimated using publicly available data including a regional maritime economic impact report [2] amongst other sources. The Port Authority wishes to collaborate with all the terminals and would welcome additional primary data to strengthen the understanding of carbon emissions and other pollution within the Port of Detroit region.

High quality activity data (fuel quantities, hours of operation, etc.) gives the team confidence in the accuracy of the calculated emissions. However, as with any complex carbon assessment, subsequent studies could identify additional sources of emissions and more accurate primary data could be procured.

Electricity Emissions

Electricity generation creates carbon emissions, with the level of emissions determined by the utility providers' energy sources. Southeast Michigan's sole utility provider is DTE Energy, which has the responsibility of decarbonizing the grid. DTE's fuel mix reported in 2022 is nearly 70% fossil fuels, comprising 54% coal, and 14% natural gas [25], however, DTE has outlined its plans for decarbonization. Shifting away from coal and natural gas towards lower carbon forms of energy generation is essential to decarbonizing the grid, and thus the Port of Detroit. The Port has a high demand for electricity, which is only likely to increase as this Plan outlines electrification of equipment as a key strategy. DTE is working to phase out coal powered plants in the region by 2032. Its goal is to reduce carbon emissions by 90% by 2040, and to reach net zero carbon emissions by 2050 [26]. This goal by the utility provider is less ambitious than the Port's hope to fully decarbonize by 2040.

Primary Emission Sources Within the Port of Detroit

SHIPPING

Shipping of bulk goods and liquid products takes place on bulk carriers, or 'Lakers', largely powered by heavy fuels such as Marine Gas Oil (MGO) and Heavy Fuel Oil (HFO). These vessels are compatible with biodiesel, which is the overriding decarbonization strategy for these vessels.

International ships can reach Detroit via the St Lawrence Seaway, a series of locks connecting the Great Lakes to the Atlantic Ocean. Due to the width of the seaway, only ships up to a certain size can pass through. These are nicknamed 'Salties' as these ships traverse the ocean salt water before coming into the freshwater Great Lakes. Primarily, Nicholson Terminal and Dock receives international cargo within the Port, including cement from Turkey, steel coils, slabs and aluminum, and heavy machinery from Europe.

In addition to the 'Lakers' and 'Salties', a number of smaller vessels operate on the water, including the Detroit Princess and the Diamond Jack (both carrying passengers for tours of the river along with offering meals), cruise ships that travel around the Great Lakes, the Detroit Police Harbor Master, Wayne County Sheriffs Marine Division, the U.S. Coast Guard, and tugboats. Primarily powered by diesel, both biodiesel and electrification can be implemented, where possible, in these smaller vessels to reduce shipping related emissions.

Figure 12: *Left; Bulk Carrier, right; the Detroit Princess.*

GOODS HANDLING

Moving bulk material and cargo on-site often requires diesel-powered mobile equipment such as wheel/front-end loaders, forklift trucks, and cranes. Diesel emissions from this equipment contribute to the majority of emissions in this category. Further, electricity emissions for pumps moving liquid products and conveyor belt systems have also been calculated. Currently, DTE's fuel mix is nearly 70% fossil fuels, 54% of this coal, and 14% natural gas [25]. Decarbonizing the grid is essential to reduce electrified equipment emissions.

Figure 13: *Left; Wheel Loader, right; conveyor belt moving goods.*

DRAYAGE

Most of the onward transport for goods from the port is carried out by semi-truck, with some use of rail. Trucking has the highest carbon emissions per ton-mile compared with other modes of transport, 6 times higher than rail transportation and 10 times higher than ships. However, to complete delivery to local warehouses or job sites, some last mile trucking is necessary. Trucks are predominantly diesel-powered and contribute to poor air quality and noise within communities. Further, there are safety concerns around the high quantity of trucking near homes, schools, and local amenities.

Figure 14: *Left; Detroit Highway, right; truck moving through Detroit.*

Calculation of Carbon Emissions at Terminals

To calculate the carbon emissions at the Port's terminals, data on carbon-emitting activity needed collecting. Data used in the emissions calculations included a combination the following:

- **Shipping:** total tonnage per shipment, number of shipments per terminal, size of the vessel, fuel type and quantity used in the vessel.
- **Goods Handling:** total tonnage of goods moved on-site, equipment list, fuel use (gallons), hours of operation, and an overview of the site operations.
- **Drayage:** total tonnage per vehicle, mode of transportation (truck or rail), type of fuel used, distance traveled, and total number of vehicles used annually.
- **Administration:** Electricity and natural gas usage (either annual usage or monthly bills provided). If not available, an estimate was performed based on the office square footage.
- **Employee Commuting:** Number of employees, average employee commute, and vehicle type were noted.

The above is the list of data collected to perform the emissions calculations. Most terminals were able to provide some of this data. However, if this data was not available, or the terminal was a non-participant, their usage of fuel and tonnage data were estimated based on similar terminals and publicly available data.

Emission calculations followed the EPA's emission port inventory guidance [27] and using their emission factor hub [28]. This is standard practice for calculating carbon emissions and was applied to the Port of Detroit for the specified boundary for the movement of goods related to the maritime activity at terminals within the Port.

EMISSIONS DATA

The total carbon emissions have been quantified at each terminal within the Port of Detroit, either using primary data provided directly from the organization or estimating based on publicly available data, for the 2022 calendar year. Emissions were calculated in metric tons of carbon dioxide equivalents (tCO_2e) per year. These emissions were determined using the U.S. EPA's Emission Factor database. Emissions calculations rely on data provided by the terminals. This data collected included fuel use data, vessel, and truck logs (detailing tonnage and mileage), goods handling equipment inventories, and utility bills. Where data was not available, estimates were made to determine fuel used in the movement of goods associated with the Port.

The overall emissions for the Port of Detroit were found to be **30,269 tCO_2e**. This total volume of carbon dioxide emitted due to port activity during 2022 is equivalent to the amount of carbon dioxide it would take to fill up Ford Field, the Detroit Lions Professional Football Team's stadium, nearly 44 times.

Total emissions for these three scopes are 8,425 tCO_2e for shipping, 4,145 tCO_2e for goods handling, and 15,430 tCO_2e for drayage. Drayage accounts for more than half of the carbon emissions due to port activity, making up 51% of the baseline. Fuel burned during ship movement and loading/unloading represents 28% of overall emissions. Goods handling equipment accounts for 14%, yet it has a high potential for reduction as the terminal operators own this equipment, whereas large vessels and trucks are primarily owned and operated by third parties. Additionally, administrative functions of port facilities (including utilities and employee commuting) make up 7% of the overall emissions, at 2,268 tCO_2e. The graphic below visualizes the breakdown of the overall Port of Detroit carbon emissions for the baseline year of 2022.

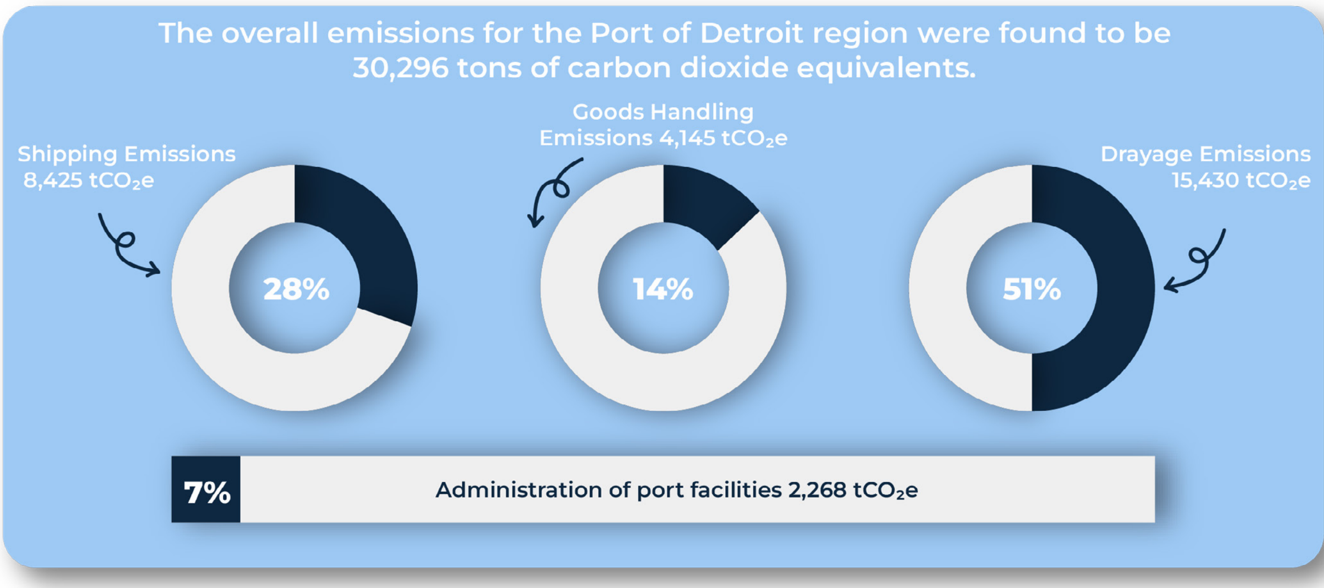


Figure 15: *Emissions for the Port of Detroit from shipping, goods handling, drayage activities, and administration functions.*

Port Emissions: Shipping, Goods Handling, and Drayage

Terminals vary in the size and type of activity within the Port of Detroit. Therefore, each individual terminal's carbon emissions will vary based on the type of equipment used, the size of an operation, and the type of fuel used. To get a better understanding of the distribution of emissions from the terminals, the table below shows the breakdown of that carbon footprint for each organization with port activity on the Detroit River or River Rouge, including shipping, goods handling, and drayage emissions. Each terminal has received a personalized plan to reduce these port operation-related emissions, with additional recommendations to improve overall air quality.

Terminal Name	Industry Type	Shipping (tCO_2e/yr)	Goods Handling (tCO_2e/yr)	Drayage (tCO_2e/yr)	Total Emissions tCO_2e/yr)
AJAX Asphalt	Liquid Asphalt Terminal	49	46	383	**477**
Carmeuse Lime	Limestone	22	173	153	**348**
Cleveland Cliffs	Steelmaking	845	1,187	4,406	**6,438**
Detroit Harbor Master	Police Boats	76	0	0	**76**
Detroit Princess	Dinner Cruise Boat	306	0	0	**306**
Detroit Salt Co.	Salt Export	99	120	83	**303**
Detroit/Wayne County Port Authority	Port Authority & Cruise Ships	1,182	0	0	**1,182**
DTE Zug Island	Coke Production for Steelmaking	665	926	3,464	**5,055**
Gaelic Tugboat and Diamond Jack	Tugboat Company and Tour Cruises	1,943	0	0	**1,943**
Great Lakes Towing	Tugboat Company	607	0	0	**607**
Holcim/LaFarage	Cement	538	310	899	**1,747**
J.W. Westcott Co.	Mail Delivery & Patrol	60	0	0	**60**
Levy	Cement/Aggregates	274	191	2,140	**2,604**
Marathon Oil Co.	Oil Terminal	314	81	0	**395**
Marine Pollution Control	Spill Cleanup	38	0	288	**326**
Michigan Marine Terminal	Oil and gas Terminal	83.1	174.2	388.9	**646**
Nicholson: Detroit Terminal	General Cargo Dock	40.5	132.1	294.9	**467**
Nicholson: Ecorse Terminal	General Cargo Dock	124	306	684	**1,114**
SRM Concrete	Cement	7	8	58	**73**
St Mary's Cement	Cement	276	338	2,219	**2,833**
Superior Materials (Levy Owned)	Cement	53	161	0	**214**
U.S. Army Corp of Engineers	River Dredging	534	0	0	**534**
U.S. Coastguard	Coastguard	112	0	0	**112**
Waterfront Petroleum Aggregate Dock	Aggregate Storage	40	167	115	**322**
Waterfront Petroleum Fuel Dock	Refuelling Station and Oil Storage	193	86	0	**279**
Total Emissions		**8,425**	**4,145**	**15,430**	**28,000**

Table 1: *Emissions are broken down by individual terminals within the Port of Detroit for shipping, goods handling, drayage, and overall activity. Holcim provided fuel usage logs for each individual shipping journey, achieving the highest level of data reporting. The terminals shaded in grey did not participate in this project by sharing data.*

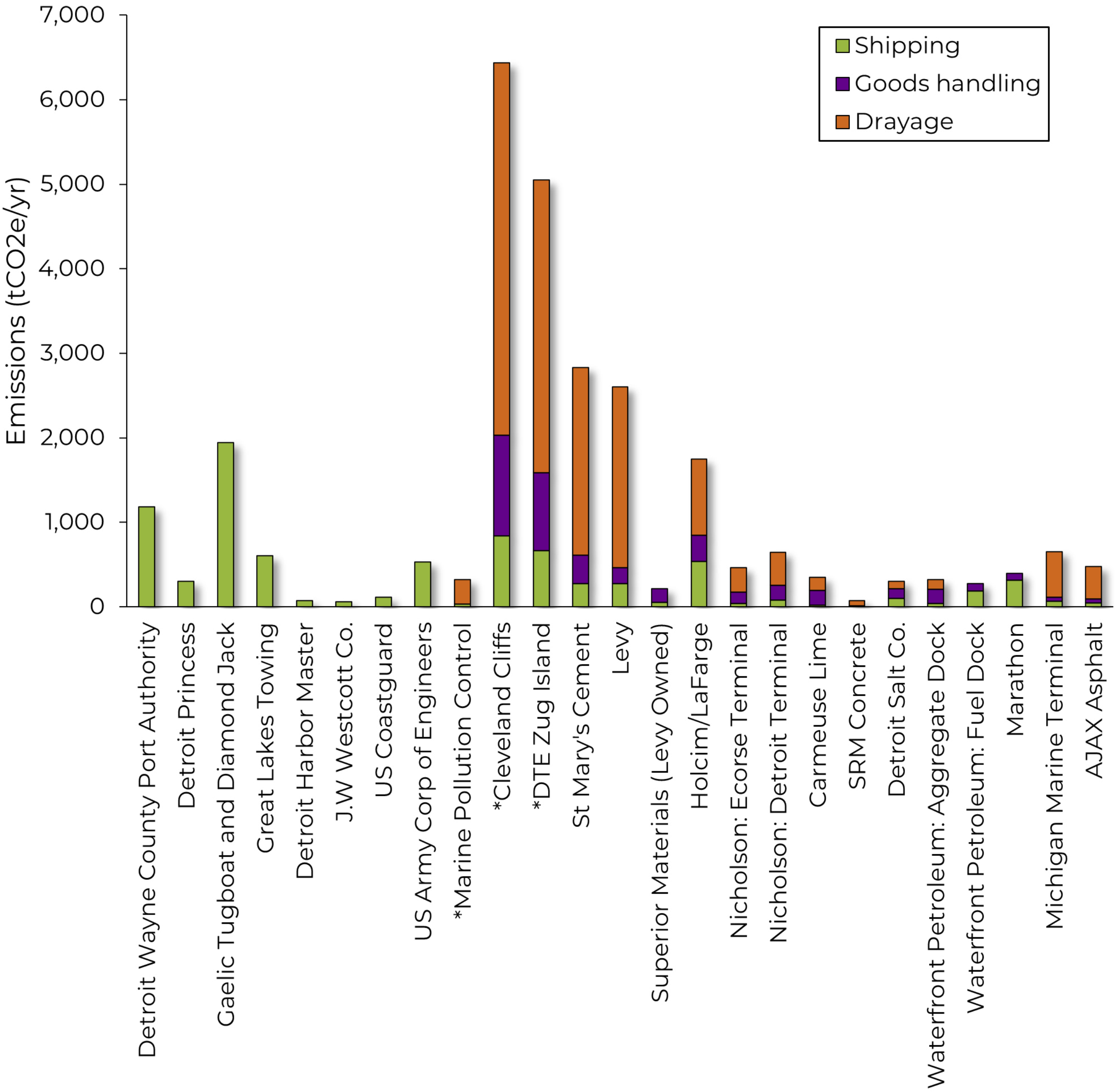


Figure 16: *Emissions for individual terminals, broken down into shipping, goods handling, and drayage. Those noted with an Asterix (*) are terminals that did not provide data; thus, emissions are estimated.*

Administrative Functions: Utilities and Employee Commuting

This project primarily focused on the carbon emissions related to the fuel used for the movement of goods throughout the Port of Detroit. However, maintaining an office for administrative functions and employee commuting have additional emissions. In this section, baseline utility emissions are calculated from primary data (information supplied by terminal operators such as utility bills) or estimated from the office area for both electricity and natural gas usage. Commuting emissions are estimated from the number of employees and the average commute (except for where primary data were supplied). The methodology, results, and emission reduction strategies are also outlined in more detail within **Appendix E** for commuting and office administrative emissions.

Commuting in the Port of Detroit for port-related employees was estimated to be 1,031 tCO_2e emitted for the baseline year, assuming an average commute is 20 miles in one direction in an average gasoline-powered vehicle.

Utility emissions for the Port of Detroit terminals were estimated to be 1,237 tCO_2e for the baseline year. The majority of these emissions are from electricity use, 1,121 tCO_2e, and the remainder are due to natural gas use on-site for heating, 116 tCO_2e. In cases where energy use was not provided, office square footage was used to estimate overall electricity (kWh) and natural gas (ccf) demand.

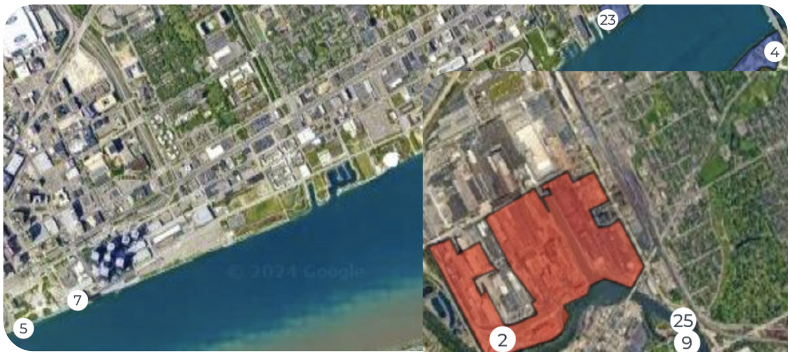
Overall, the administration functions that are responsible for significant levels of emissions within the port region include commuting and utilities. The total administrative function emissions for the baseline year are 2,268 tCO_2e. Administrative emissions are broken down by individual terminals in **Appendix E**.

Figure 17: *Detroit skyline across from Windsor.*

OUTCOME: INTERACTIVE MAP OF EMISSIONS

To ensure robust transparency, the results of the port-wide baseline carbon assessment are available via the **Port Authority's website** and can be viewed through an interactive mapping tool. The interactive map shows the location of all port-related operators along the Detroit River and River Rouge, along with each location's carbon emissions data. Annual updates will be provided to measure the progress of the carbon reduction initiatives for individual terminals as they pursue net zero by 2040.

Emissions are broken into the three categories of shipping, goods handling, and drayage for each terminal. Terminals that have participated in the study are displayed in blue, while non-participating terminals are shaded in red, to distinguish measured from estimated baseline emissions. The Port Authority thanks those organizations who provided data in this project, as calculating a baseline is the first step towards reducing emissions; the remaining entities are encouraged to join in this process and provide internal data to allow for a more accurate assessment. Any successful emissions reduction strategies implemented will be included on the **Port Authority's website** to point to the efforts being taken by these organizations to decarbonize.



TERMINALS

1. AJAX Paving Company
2. Cleveland Cliffs
3. Carmeuse Lime
4. Detroit Harbor Master/ Sheriff Department
5. Detroit Princess
6. Detroit Salt
7. Detroit/Wayne County Port Authority
8. DTE Zug Island Operations
9. Gaelic Tugboat and Diamond Jack's Rivertours
10. Great Lakes Towing
11. Holcim
12. SRM Concrete
13. J.W Westcott
14. Levy
15. Superior Materials
16. Marathon Oil Company
17. Marine Pollution Control
18. Michigan Marine Terminal
19. Nicholson Terminal and Dock (Ecorse)
20. Nicholson Terminal and Dock (Jefferson)
21. St Mary's Cement
22. US Army Corp of Engineers
23. US Coastguard
24. Waterfront Petroleum (Fuel Facility)
25. Waterfront Petroleum (Aggregate Facility)

VIEW THE MAP

Figure 18: *The interactive maps show active terminals in the Port of Detroit. They are numbered above and can be accessed to see up to date emissions data for each terminal.*

PORT WIDE EMISSIONS REDUCTION STRATEGY

The timeline below outlines the Port of Detroit's projected pathway to net zero by 2040. These targets primarily focus on the use of biodiesel as the immediate implementation strategy, alongside electrification and the use of other low-carbon fuels.

- Switch to biodiesel in compatible equipment immediately.
- Biodiesel is the main strategy for large vessels.
- Electrify where possible, mainly in small vessels, goods handling equipment, and trucks.
- Implement other low-carbon technologies as they become cost-effective and available.

PORT OF DETROIT CARBON REDUCTION ACTION STEPS

2024	2027	2030	2035	2040
BASELINE Carbon emissions inventory done for each terminal operations within the Port of Detroit, using 2022 data.	**SHIPPING** • 20% Large vessels on biodiesel	**SHIPPING** • 50% Large vessels on biodiesel • 50% Small vessels electrified	**SHIPPING** • 80% Large vessels on biodiesel • 80% Small vessels electrified	**SHIPPING** • 100% Large vessels on biodiesel • 100% Small vessels on biodiesel • Phase in hydrogen or other zero emission fuel
	GOODS HANDLING • 50% Equipment on biodiesel	**GOODS HANDLING** • 100% On biodiesel • 100% Electricity purchased is renewable	**GOODS HANDLING** • 100% Zero emissions equipment	
	TRUCKING • 50% Of trucks on biodiesel	**TRUCKING** • 50% Of trucks are on zero emissions (hydrogen or electric) • Remainder are biodiesel powered	**TRUCKING** • 80% Of trucks are zero emissions (hydrogen or electric) • Remainder are biodiesel powered	**TRUCKING** • 100% Of trucks are zero emissions (hydrogen or electric)

Figure 19: *Port of Detroit roadmap to reach net zero by 2040.*

Additional Recommendations: Pathway to Net Zero

Aside from shipping, goods handling, and drayage fuel upgrades, additional recommendations exist for the Port of Detroit region. These are primarily around using renewable energy and becoming members of Green Marine to certify continual improvement of emission reduction.

- Aim to have 100% of port-related electricity use on-site and within office spaces powered by renewable electricity (purchased or generated on-site) by **2030**.
- Aim to have 75% of the region's cargo arrive at Green Marine Certified Terminals by **2030**.
- Aim to have 100% of terminals in the Port of Detroit Green Marine certified by **2040**.

ALTERNATIVE FUELS TO ACHIEVE EMISSIONS REDUCTION

The Port Authority's overall set of recommended strategies to reach net zero emissions for the port region by 2040 includes transitioning from fuel sources with high carbon emissions to those with much lower emissions. The low-carbon fuels for shipping, goods handling, and drayage applications are outlined below,along with basic information, benefits to people and the environment and challenges for implementation. Additional technical information can be found in the **Appendices.**

BIODIESEL: The most common blend of biodiesel available is B20 (20% biodiesel, 80% diesel), and switching to this can result in a 14.8% reduction in carbon emissions compared to pure fossil diesel. B100, (100% biodiesel) achieves a 74% reduction in carbon emissions. Biodiesel can be blended at any level. The benefit of this blending ability of biodiesel is cost (higher blends are currently more expensive than diesel) and operational variance (higher blends can be affected by cold weather). Since biodiesel can be used in existing vessels, equipment, and trucks, there is no requirement for high capital expenditure. Biodiesel provides an opportunity for immediate carbon reduction, increasing with higher blends, improvements in air quality, extends the lifetime of existing equipment and offers a low-carbon option where electrification and zero-emission alternatives are not yet available [29].

Figure 20: *Soybeans and gas pump.*

- Compatible with existing vessels, trucks, and goods handling equipment.
- Similar price to diesel with existing subsidies.
- B100 has a 74% carbon reduction, with lower particulate matter and hydrocarbon emissions as well.

ELECTRIFICATION: Electrification is a zero-emission strategy that can work to reduce local carbon emissions and air pollution. Co-benefits to electrification include the potential for lower lifetime costs, less noise and vibration, and improved air quality, in addition to reduced carbon emissions. The greatest carbon reduction is achieved when powered by renewably generated electricity. DTE has a program called MI Green Power [30] where customers can purchase up to 100% renewable energy. Currently, the DTE grid is approximately 70% powered by fossil fuels [25], so transitioning to renewables is essential to decarbonize. The combination of electrification at the point of use, and renewable generation will reduce carbon emissions associated with port-related equipment to near zero. Currently, smaller vessels, some goods handling equipment, and trucks have electric models available to purchase. Capital costs for electric equipment is higher than diesel equivalents, The much-reduced running costs lead to lower lifecycle costs, and therefore a competitive advantage in both environmental and financial terms.

Figure 21: *Electric tug boat.*

- Lower operational costs.
- Potential lower lifecycle costs.

- Much reduced criteria air pollutants.
- Available for certain vessels, small equipment, and trucks.
- Combine with renewable energy purchase for the greatest emissions reduction possible.

HYDROGEN: Hydrogen (green hydrogen) is an environmentally friendly fuel, where low-carbon electricity is used to turn water into hydrogen and oxygen, in a process called electrolysis. Using green hydrogen in trucks does not generate carbon emissions. Gray hydrogen is made from natural gas, a process that still generates carbon emissions. Blue hydrogen uses the same process as gray hydrogen, coupled with carbon capture and storage to reduce emissions. As of 2023, less than 1% of global hydrogen production is either green or blue (low-carbon), because gray hydrogen is a cheaper process. The creation of green hydrogen requires the use of electricity as a feedstock, so large amounts of energy are used to make hydrogen sustainably. However, hydrogen has many clear benefits, making research and development of low-carbon processes worthwhile. Electrolysis is a known technology, there are zero tailpipe emissions, refueling is fast, and it has wide support in the U.S. The applications are especially promising for large vessels, heavy equipment, and trucks that require a lot of power. The Port of Detroit is a member of the **Midwest Alliance for Clean Hydrogen** which was approved for U.S. Department of Energy funding to develop a regional Hydrogen Hub [31]. Development of green hydrogen in ample supply and with suitable equipment available at scale will likely take 7 to 10 years to develop. Equipment powered by green hydrogen has zero tailpipe emission and offers greater energy storage than battery electric equivalents (as of 2024) with longer ranges and shorter refueling times. Grant funding is currently available (for all hydrogen, regardless of source) and further technological developments may bring down the cost of green hydrogen over time. In addition, green hydrogen has far reduced particulate matter, SO_x, and NO_x emissions, lower engine noise and vibrations, reducing community impact compared to diesel.

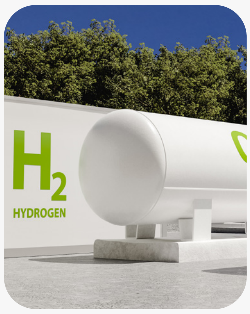


Figure 22: *Hydrogen containers.*

- Low emissions.
- Dense fuel suitable for industrial applications
- Estimated 7-10 years until commercial viability.

LOW-CARBON SHIPPING FUELS: GREEN AMMONIA AND GREEN METHANOL: These fuels typically need green hydrogen as a starting point for production, therefore, the cost and efficiency implications of hydrogen (outlined above) also apply to these fuels. In addition to the generation of green hydrogen, further processing is required, adding to the cost per unit of energy. Green methanol can be made using waste plant matter, and this processing leads to high costs.

Figure 23: *Ammonia tank.*

Another challenge with ammonia and methanol is the density of the fuel. Both fuels are less energy dense than diesel, where the range is about half the distance of current diesel engines. This translates to either more frequent refueling, or more storage space required for fuel supply onboard vessels, taking away cargo space. Additionally, subsidies are required for cost competitiveness for low-carbon methanol, ammonia, and other prospective low-carbon fuel sources [32].

INCREASED UTILIZATION OF LOWER CARBON MODES OF TRANSPORTATION: Moving goods via ship or barge has much reduced carbon emissions when compared to truck or rail (10x lower emission than trucks and 1.6x lower emission than rail). The hierarchy of emissions from low to high emission starts with shipping, rail, trucks, and finally by air (Figure 25). Trucking is often the preferred option, as it offers direct and fast door-to-door delivery. Shipping on the water often includes small amounts of last mile trucking, more logistics organization, and slower delivery. However, where possible, not only does moving goods on the water reduce emissions, but it also enhances road safety, reduces impacts from noise and vibration, and lowers costs to businesses Businesses should consider emissions, safety, and community impact when making decisions on how to move their goods.

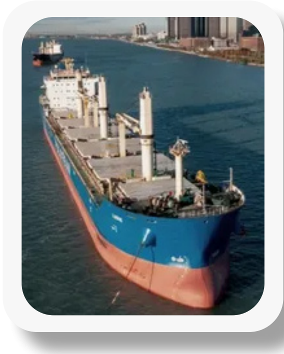


Figure 24: *Moving goods via ship.*

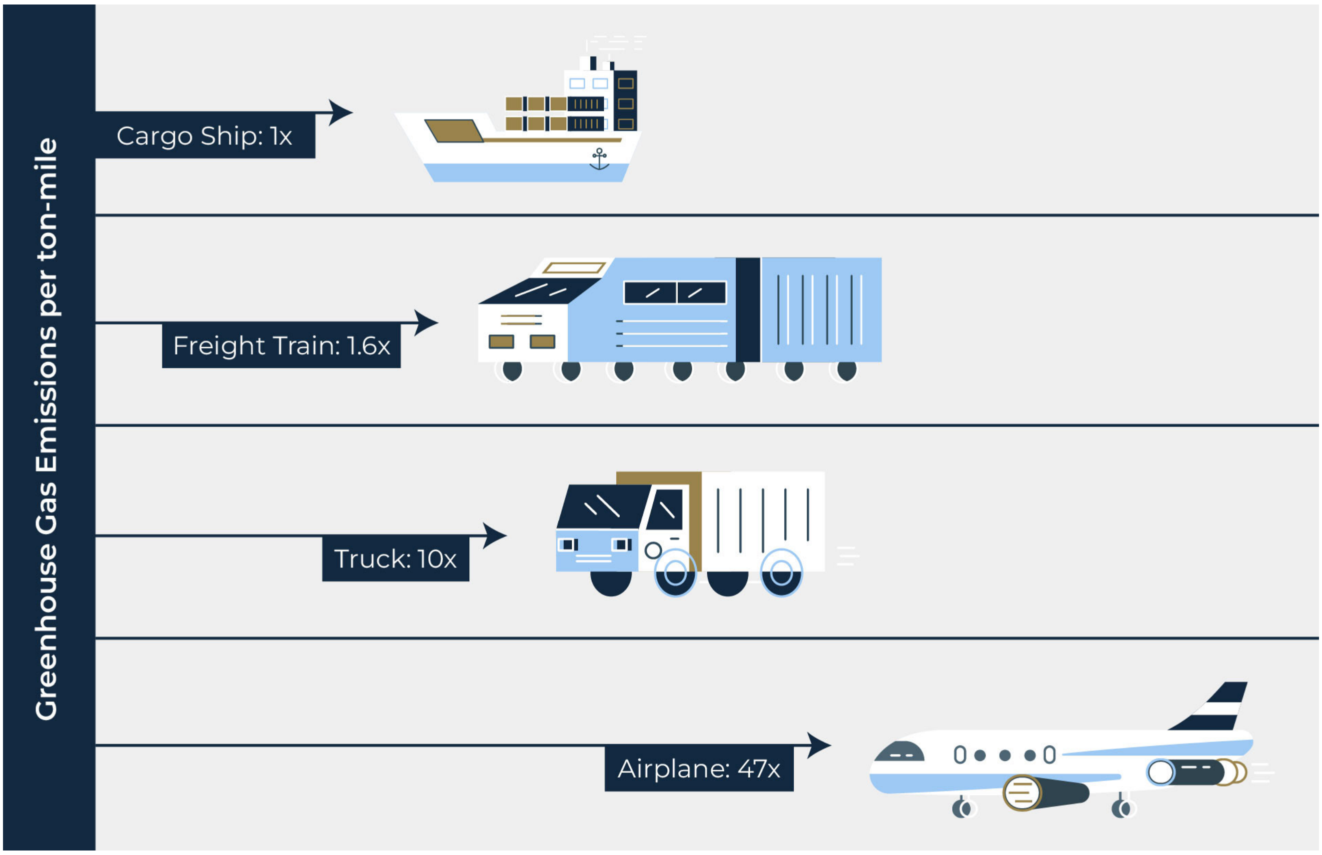


Figure 25: *Comparison of truck, rail and air freight CO_2e emissions to cargo ship carbon emissions by weight-distance [33].*

OPERATIONAL EFFICIENCIES: Increased efficiency can reduce both emissions and cost. Examples include parking trucks as close as possible to stack piles to reduce wheel loader movements and making greater use of electric conveyor belts and gravity-fed systems to move products. In addition, maintenance (regular and preventative) reduces fuel demand. Although carbon savings are lower than transitioning to low-carbon fuels, these initiatives have benefits for improving efficiencies, costs, and emissions with minor changes in working practices.

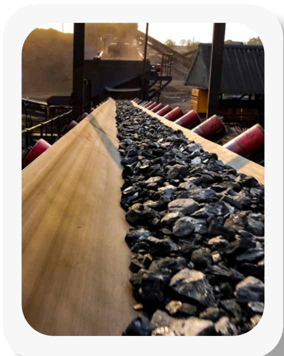


Figure 26: *Conveyor belt moving bulk goods.*

AIR QUALITY: IMPACTS AND STRATEGIES FOR IMPROVEMENT

This assessment provided the baseline level of emissions for the Port of Detroit as a whole and each individual terminal operation with a roadmap to reduce carbon emissions. Additionally, the impact on air quality that these recommended carbon reduction strategies have on harmful air pollutants is discussed, including $PM_{2.5}$, NO_x, SO_x, and in some cases Carbon Monoxide (CO) and Hydrocarbons (HC). Recommendations on best practices to further reduce the emission of harmful air pollutants are discussed, as well as best practices outlined by Green Marine for both air quality and dust mitigation [34].

Air Quality Improvements with Alternative Fuels

Biofuels: Biodiesel has the potential to make a significant and positive impact on carbon emissions and air pollution today. Biodiesel has been studied by the EPA and the U.S. Department of Energy [29], and both found it to be effective in reducing particulate matter (10.1% for B20), and hydrocarbons (21.1% for B20). Biodiesel overall has a positive impact in reducing harmful air pollutants, and results can be seen immediately without required engine modifications. B20 is the standard blend of biodiesel that is market available, with higher blends available for select applications. A B100 blend will result in the greatest reduction of harmful pollutants, as well as carbon emissions.

Electrification: Electrification results in an immediate reduction of emissions to zero at the tailpipe (point of use of equipment). There are often emissions associated with the point of electrical energy generation; we recommend that terminal operators that replace their diesel equipment and vehicles with electric versions also purchase renewable generated electricity from their energy provider. As stated above, DTE offers an option for customers to pay slightly higher rates and purchase up to 100% renewable energy through the **MI Green Power Program** [30] to help speed up the transition to renewables. Electrification of port equipment, when combined with purchasing renewable energy, offers the greatest potential to reduce harmful air pollution within the port.

Green Hydrogen, Ammonia, Methanol, or other Low-Carbon Shipping Fuels: Currently, there are no commercially available ship engines or heavy-duty port equipment that runs on these alternative fuels. A few drayage trucks are running on hydrogen; however, the supply of green hydrogen is not available in the Detroit area. In the longer term, switching equipment to be powered by low-carbon fuels would have significant reductions in reducing harmful air pollutants. Research and pilot programs are underway to power ships, heavy equipment, and trucks with the likes of green methanol, ammonia, and hydrogen. All three of these options have large emissions reductions of harmful air pollutants in addition to carbon emissions, as these are zero or near zero emissions fuels. It will be at least 7-10 years before these become realistic options for wide usage within the Port of Detroit.

Green Marine

As referenced previously, **Green Marine** is a voluntary environmental certification program for the North American Maritime Industry (and expanding internationally). To become certified, participants must assess their environmental performance annually, submit to an external verification, agree to publish their results, and commit to a process of continual improvement [35]. There are 14 performance indicators, where Green Marine provides a pathway and guidance to reduce maritime-related environmental impacts, including industry best practices for bulk handling and storage to mitigate dust emissions, noise reduction strategies, and odor mitigation, among others. Taking steps toward continual improvement in the Green Marine community impacts and air quality indicators would showcase a private terminal's dedication to improving the community and environment in Detroit. Each organization is audited annually and must undergo a process of continual improvement. The Port Authority is seeking financial support for Port of Detroit entities to obtain Green Marine membership.

Figure 27: *Green Marine Certified logo badge.*

Other Harmful Emissions

In addition to carbon emissions, criteria air pollutants, dust, and other community impacts arise from goods handling, trucking, and rail movements. Particularly acute in Southwest Detroit is dust and air pollution, with negative health outcomes such as elevated levels of hospitalizations and asthma [19]. As detailed in the report, reducing fossil fuel usage will improve air quality; however, decarbonization does not address air pollution from other sources, such as soil/dust, road salt, bulk materials, traffic, wood smoke, incinerators, and other industrial sources [36]. The Port Authority considered the impact of additional air pollution threats to health in the near port communities and recommended solutions to decrease these emissions rates from terminal operations.

Dust and Particulate Matter

Dust is a primary community concern, as it contributes to particulate matter pollution and associated poor health outcomes in the Southwest Detroit region. The city of Detroit has a dust ordinance in place, with fines ranging between $500 and $2,000 for violations. These are based on visual inspections from a site visit [37]. The city of Dearborn has recently enacted a dust ordinance, as of April 2024 [38]. Most terminals in the Port of Detroit region fall within the Detroit city boundary; however, some terminals lie within the cities of Dearborn, River Rouge and Ecorse.

Dust ordinances can vary in requirements, effectiveness, and detail. Below are some examples of what has been included in either the Detroit or Dearborn ordinances:

- Certificate of operation and a notice of a change in operation.
- Inspections on a semi-annual basis or after a complaint.
- No visible dust beyond the property line.
- Fugitive dust cannot exceed 5% optical opacity.

- A fugitive dust plan must be submitted and followed (with annual review).
- Real time monitoring using at least two PM_{10} (or equivalent) monitors.
- Monitor wind speed and direction.
- A system in place to minimize dust for conveyance (examples: total enclosure, water sprayed, transfer only wet material or vented to pollution control equipment).
- Truck speed limit (8 mph), covered trucks, paved roads on-site, and frequent washing down of trucks.
- Control of fugitive dust.
- Height limit for outdoor storage, minimum distance between storage piles and waterway.
- Establishment of enclosure requirements for carbonaceous bulk solid materials.

These well-meaning ordinances create the possibility of terminal relocations to avoid regulation, and thus reducing jobs and economic benefits. In some instances, the regulations could be seen as overly aggressive when applied to certain terminals. Both ordinances suffer from a lack of sufficient funding for enforcement and oversight. Many terminal operators and business organizations have opposed the dust ordinances outright, without offering alternatives to address the clear health issues posed by fugitive dust.

The Port Authority has recommended that terminals and business groups propose real and significant standards for managing and containing dust on terminals and agree to penalties for violations. Also, having a statewide dust standard would prevent the shifting of dust piles to the municipality with the lowest or no fugitive dust rules. In the end, the Port Authority, through this plan, will continue to work with terminals to meet **Green Marine dust and air quality standards**, and protect the community from any fugitive dust. Below are the dust and air quality standards as detailed in the Green Marine's criteria for dry bulk material handling and storage [34].

Level 1 is the monitoring of industry regulations, which is the legal minimum.

Level 2 Requirements:

2.1 Collect cargo residues on the ground as soon as possible using methods that minimize dust generation (e.g., water spraying, vacuum sweeping).

2.2 Ensure that collected cargo residues are properly stored, recovered and/or disposed of.

2.3 Take measures to prevent water contamination during loading and unloading operations (e.g., use canvas between ships and docks when unloading).

2.4 For outdoor operations, reduce dust dispersion by using one or more of the following methods, but not limited to: spraying a light mist; using screens, air or water curtains and/or drapes; reducing conveyor belt height and speed; keeping outdoor dry bulk piles covered or protected by wind shields as much as possible when they are likely to blow away by the wind or to leach out onto the ground.

2.5 Fit storm drains with screens, baskets, geo-textiles or other devices in order to filter suspended solids found in stormwater runoff and ensure that such devices are cleaned on a regular basis.

2.6 Recover cargo losses under the conveyors.

2.7 Regularly wash vehicles in dedicated areas to avoid dust dispersal on and off-site.

Level 3 Requirements:

3.1 Adopt a Water and Land Pollution Prevention plan that covers all sites that the participant operates on.

3.2 Produce an incident report and maintain records for each incident of abnormal dust or discharge accompanied by a detailed analysis of the causes and corrective measures implemented.

Level 4 Requirements:

4.1 Implement a documented Inspection and Preventive Maintenance program targeting dry cargo handling equipment and dust suppression technologies.

4.2 Adopt a procedure for managing loading and unloading operations in cases of abnormal dust emissions due to wind.
Note: The participant must have in place a procedure or a policy that defines, for each type of cargo, the adverse weather conditions that affect loading and unloading operations, and preventive measures to be taken. Procedures must also include a record of incidents and must be communicated to and systematically applied by relevant staff.

4.3 Conduct a detailed analysis of the loading, unloading, and handling process to identify critical stages, situations or areas causing dust dispersal and establish a protocol for preventative measures.

Level 5 Requirements:

5.1 Implement a documented Preventative Maintenance program targeting dry cargo handling equipment and dust suppression technologies.

5.2 Adopt a procedure for managing loading and unloading operations in cases of abnormal dust emissions due to wind.
Note: The participant must have in place a procedure or a policy that defines, for each type of cargo, the adverse weather conditions that affect loading and unloading operations, and preventive measures to be taken. This procedure must also include a record of incidents and must be communicated to, and systematically applied by, relevant staff.

5.3 Conduct a detailed analysis of the loading, unloading, and handling process to identify critical stages, situations or areas causing dust dispersal and establish a protocol for preventative measures.

5.4 Use enclosed conveyors or chutes and telescoping arm loaders, operate in a closed circuit, or other similar equipment to limit dust generation and releases into the environment.

5.5 Use dust suppression, baghouse, screw conveyors, vacuum collecting equipment or other similar equipment in the handling of fine, granular, or powdery material.

Members of the community concerned about dust can report complaints to the Michigan Department of Environmental Quality – Air Quality Division at 313-456-4700 or use the 24-hour emergency number on 1-800-292-4706. These numbers apply across Wayne County.

Noise and Vibrations

Port activity and the industrial processes located near the Port produce high levels of noise. This is due to the operation of heavy machinery and equipment, including ships, goods handling equipment, trucks, and rail. Trucks have the greatest community impact due to truck routes that are often in close proximity to homes and schools. Green Marine has guidance for ports to reduce noise levels and the overall impact on the community. Noise mitigation strategies include limiting the idling of vehicles, ensuring proper maintenance of machinery, purchasing quieter equipment (such as electric equipment), installing noise barriers near residential areas, and monitoring noise in appropriate locations [39].

Air Quality Monitoring

Detroit is frequently in non-attainment (a term that refers to too much of a dangerous air pollutant, at levels above the national air quality standard) for sulfur dioxide and ozone emissions [40] and will likely be a non-attainment area for $PM_{2.5}$ as stricter criteria are implemented (reducing from 15 µg/m^3 to 9µg/m^3)[41]. The national air quality standards for criteria air pollutants can be found on the **EPA's website** [42]. This pollution is the result of burning fossil fuels, among other activities within the Port of Detroit that contribute to the poor air quality due to ship and truck movements, as well as heavy diesel equipment. To understand more nuanced air quality levels around the city of Detroit, air quality monitoring systems can be deployed and utilized to measure real-time levels of pollution. Monitors can also be used to show the change in air quality over time, as low-carbon fuels and zero-emissions technologies are implemented in the port region. The Port Authority is planning to install additional air quality monitors, partnering with Just Air Solutions, a Detroit-based company, to collect and display this data publicly to residents and businesses in Detroit. If you are a resident of Detroit or Wayne County and are interested in receiving air quality alerts and information, sign up to receive alerts from **Just Air** on their website.

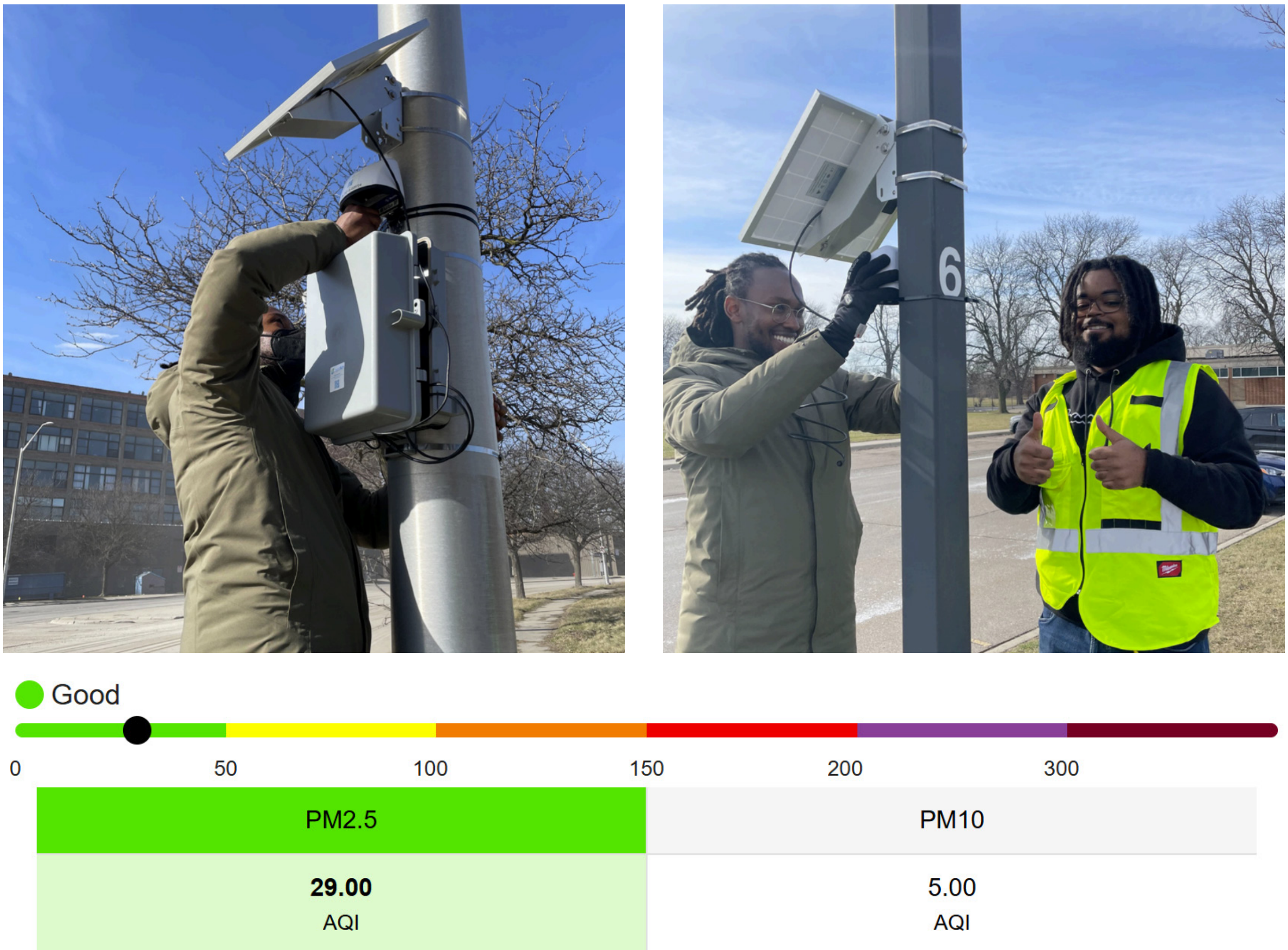


Figure 28: *Installation of Air Monitors in the Detroit region by Just Air (Top Left and Right). The Environmental Protection Agency's national scale for measuring air quality index (Bottom)*

CONTINUED ENGAGEMENT AND COLLABORATION

Low Carbon Port Committee

To ensure the longevity of this project, the Low Carbon Port Committee of terminal operators was formed. The aim of this group is to have regular meetings to discuss low-carbon technology availability and seek funding as a group for implementation. The committee is a voluntary group, facilitated by the Port Authority, comprised of several terminal operators who participated in the Plan.

The purpose of the committee is to:

- Implement carbon reduction and air quality improvements, and collaborate by sharing best practices, along with lessons learned.
- Collect data for the Port Authority to provide regularly updated emissions reports.
- Monitor and apply for grant applications.
- Continual assessment of new technology or other opportunities to deliver carbon reduction, air quality improvements, or otherwise enhance environmental or social sustainability.

Decarbonization and Air Quality Improvement Plan Advisory Board

To ensure continued engagement with the community, the Port Authority plans to start the Decarbonization and Air Quality Improvement Advisory Board, comprised of community members, environmental justice organizations, local businesses, religious groups, and government officials. The aim of the board is to hold the Port Authority and terminal operators accountable for achieving reductions in carbon and other harmful emissions. The board will also work to ensure the community stays up-to-date and informed of complementary initiatives that seek to reduce carbon emissions and other harmful pollutants in the Detroit area. Additionally, the board will seek to foster collaboration between the Port Authority and other organizations working to decarbonize our region.

The Pathway to Net Zero by 2040

The Port Authority acknowledges the impacts port operations and port-related activity has on the health and quality of life for people of this region. Through this project, the Port Authority seeks to join the many organizations and community members who have, for many decades, been fighting for improved air quality in this heavily industrialized city. Additionally, there are efforts at the municipal, county, state, and federal levels of government to lower emissions. This Plan supports and supplements those efforts with recommendations to port terminal operators to go beyond simply eliminating fossil fuels. Collaboration is needed between government entities, private companies, community organizations, and community members, to pursue funding and regional projects that have the ability to reduce harmful air pollutants.

GREEN PORT OF DETROIT

Decarbonization Challenges

The net zero pathway for the Port of Detroit has been outlined in this report, and individually for all dock operations, and if followed, will result in a net zero port region by the year 2040. The majority of emissions can be reduced through transitioning from diesel to alternative fuels such as biodiesel and hydrogen, the electrification of goods handling equipment and smaller vessels, the purchase and/or generation of renewable electricity within the Port of Detroit, and the transition towards low-carbon fuel use within large vessels on the Great Lakes. These strategies will get the Port of Detroit to near zero carbon emissions. Offsetting will likely be required to reach net zero for residual emissions. Nevertheless, all plans need to account for potential obstacles or setbacks. Below are key factors for the successful implementation of the Plan.

Prioritize Decarbonization: The Port of Detroit is a collection of private businesses, all requiring organizational change. For net zero carbon emissions in the Port to be achieved, decarbonization needs to be high on the agenda of all organizations involved, and discussed at the leadership level regularly. The actions of business leaders, policymakers, utility providers, and other stakeholders are key to delivering the port-wide strategy and meeting intermediate targets, as well as net zero by 2040.

Collaboration: Continued engagement from the terminal operators is important to assess progress, as emissions are recalculated each year, as well as to provide opportunities to collaborate among the terminals in port-wide decarbonization efforts. Strong community engagement, to keep members of the community informed and involved in decision-making, will create pathways to improve community relationships, and provide local support for emission reduction initiatives.

Funding: Cost is a key driver for businesses. Therefore, carbon reduction initiatives that can save money will be considered first. Electric goods handling equipment often has a higher capital cost, with the promise of lower running costs leading to long-term cost savings. Combining grant funding or using financial tools such as lease agreements can help overcome some of the challenges associated with the initial expense of electrification. Grant funding and tax incentives play an important role in encouraging people and businesses to change their behavior and adopt new technology. Therefore, government officials at city, state and federal levels need to be committed to the Paris Agreement and reducing carbon emissions. To put priorities in context, the U.S. spent approximately $760 billion on fossil fuel subsidies in 2022. Were this capital to be spent on green infrastructure and sustainable fuels, much greater progress towards net zero could be accomplished.

Technical Advances: The benefits and costs of shifting to biofuels are well understood, and although they serve as an opportunity for immediate carbon reduction, biofuels are to serve primarily as a transition fuel. Achieving net zero will require technical advances and investment in lower carbon and zero carbon fuels. Battery electric vehicles need longer range, materials recycling, and other efficiencies to be adopted widely. Similarly, other low-carbon fuels such as green ammonia or green hydrogen have even more uncertainties associated with them. Fuels such as green hydrogen are highly dependent on a reliable and low-cost source of renewable energy; however, energy is lost when converting electrical energy into chemical energy. Some means of making green methanol also rely on the availability of electricity. In addition to the increased production of these fuels, there needs to be a large enough market to sell to for economies of scale. How these developments progress depends on technology, legislation, costs of renewable electricity and demand. Due to these uncertainties, it is difficult to predict which will become the fuel of the future in the maritime sector. There are clear co-benefits to using these alternative fuels to motivate the switch beyond GHG emission reduction. These include improved energy security, reduced air pollution, increased health and reduced healthcare spending, to name a few.

Operational Control

Implementing the Decarbonization Plan will require bold action to change fuels quickly and eventually invest in new cargo handling equipment, vehicles, trucks, trains, and ships. Unfortunately, the Port Authority does not own or control any of these items. It also lacks regulatory power to impose decarbonization standards in the Port. Unlike most other port authorities, the Detroit/Wayne County Port Authority does not own and lease land to terminals and cannot influence change through contractual lease requirements.

Similarly, the terminal operators in the Port have direct control of only about 15% of carbon-emitting assets attributed to their port activity in this study. Most trucks, trains, and ships that bring cargo into and out of the Port are owned by a wide range of fleet owners and shipping companies, not under direct control or contractual affiliation with the terminal owners. Nevertheless, the Port Authority and terminal owners who have come together to formulate this Plan can continue working together to influence change by talking to shippers and fleet owners about the advantages of decarbonization and supporting legislation that incentivizes carbon reduction, among other things.

One point of leverage the Port Authority has as an organization is the ability to seek grant funding for equipment and capital improvements for terminals, provided they are implementing decarbonization measures. The Federal government has provided billions of dollars to terminals through its Port Infrastructure Development Program (PIDP) and similar programs. Private entities may benefit and receive, in some cases, as much as 90% of the project costs paid for by the grant. However, the programs require a lead applicant like the Port Authority to qualify and serve as the fiscal agent for the funds. The Port Authority is an active applicant for federal funding and recently received approval for Clean Ports grant funding to implement zero emission equipment, vehicles, and boats in the Port. The Port Authority will continue to leverage grant opportunities to advance the Decarbonization Plan goals.

IMPLEMENTATION: THE PATH TO A NET ZERO 2040

Since the establishment of the automotive industry, Detroit began its journey to becoming one of the most industrialized and polluted regions of the country. While industrialization brought jobs and economic growth, levels of toxic air pollution have risen with the rise of heavy industry and associated use of fossil fuels. Detroit has also experienced a rise in air pollution, high volumes of truck traffic traveling through neighborhoods, noise pollution, and of course, significant contributions to global greenhouse gas emissions. If this decarbonization plan is carried out, along with similar plans initiated by local businesses and government agencies in Southeast Michigan, many of the negative impacts on residents can be mitigated, leading to an overall healthier and safer port community. Jobs, health, and a clean environment can coexist, and the pursuit of green initiatives will provide a path forward for businesses to prioritize sustainability.

Reaching net zero by 2040 through this plan provides the framework for Detroit to be one of the first of the Great Lakes Ports to achieve net zero and impact decarbonization more widely in the maritime industry. The level of collaboration and voluntary participation made between the launch of this study and completing the baseline assessment has surpassed all expectations. Prior to this report, these private businesses showed little in the way of collaborative sustainability. Now, 21 out of the 24 entities have made the courageous decision to supply business sensitive information to inform the Plan. The formation of the Low-Carbon Port Committee, meeting regularly to address greenhouse gas emissions, and air quality creates the forum for continued bold action. With this momentum, the ambitious targets set out in the Plan can certainly be achieved.

Detroiters are committed to improving their city, and this strong sense of community will help successfully move the Port of Detroit to decarbonize. The Port Authority strongly supports the growing regional decarbonization efforts and looks forward to achieving a greener future in Detroit together.

Figure 29: *Detroit/Wayne County Port Authority building, viewed from the Detroit RiverWalk.*

APPENDIX AND SUPPLEMENTAL MATERIALS

Appendix A: Emissions Reduction Strategy: Biodiesel

The Port of Detroit Decarbonization Plan recommends the utilization of biodiesel to reduce carbon emissions immediately for all port equipment, vehicles, trucks, trains, and ships that currently use diesel. Over time, as zero-emission equipment and vehicles become more available and affordable, the Plan recommends shifting to that technology for everything except ships, for which alternative fuels and technology may take longer to develop. Biodiesel has a high carbon reduction potential per dollar spent and can be implemented quickly, and at scale. This section explains in more detail what biodiesel is and why it is the leading initial recommendation in the Plan.

What is Biodiesel?

Biodiesel is a renewable, biodegradable fuel derived from vegetable oils, animal fats, or recycled cooking grease. Biodiesel is commercially available, and used in diesel engines, boilers, and oil heating systems, and can either directly replace diesel, or be blended.

To create biofuels, the feedstock of oils, fats, and/or grease is mixed with 10% by weight methanol, and a catalyst (typically sodium hydroxide) (Figure A1). This process creates biodiesel (of a similar weight to the feedstock) and 10% glycerin as a by-product. Like fossil fuel derived diesel, biodiesel must conform to the ASTM D6751 standard to be sold on the open market, which stipulates a minimum cetane number of 45 for on-road biodiesel. This excludes marine fuels and heating oil. Cold weather can affect performance (with crystallization for example) therefore some fuel suppliers use a flow improver or change the biodiesel blend. The characteristics are specific to each fuel combination; users should work with suppliers to find the right biodiesel blend. Most diesel equipment is readily compatible with B20, with carbon emissions savings of 15% compared to fossil fuel diesel. Some equipment can run on up to B100 biodiesel; users should consult the equipment manual to see if the manufacturer's warranty covers this fuel blend.

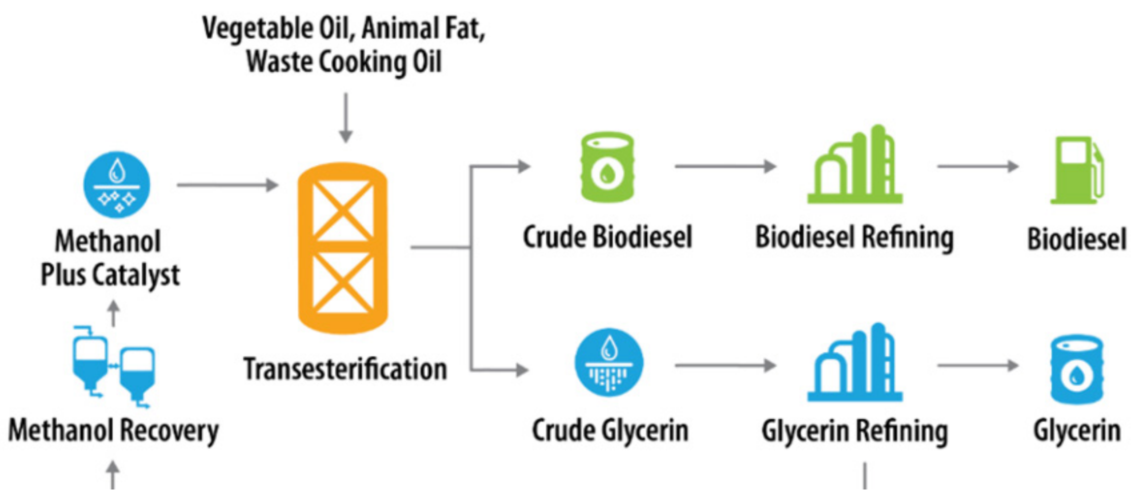


Figure A1: *Basic biofuel production process using transesterification [73].*

Renewable diesel is similar to biodiesel, but instead of transesterification with methanol and a base, the oils undergo hydrotreatment, to remove impurities in the fuel. Although more expensive than biodiesel, renewable diesel matches the ASTM D975 standard for regular diesel, so it is completely interchangeable and does not have the cold weather limitations of biodiesel.

How do Biofuels Reduce Emissions?

Biodiesel has a range of potential feedstocks, sources, and processing facilities, which can impact the reduction in carbon associated with a particular scenario. Figure A2 shows the carbon intensity of biodiesel based on the input. However, the fundamentals of the carbon cycle apply to all biofuels.

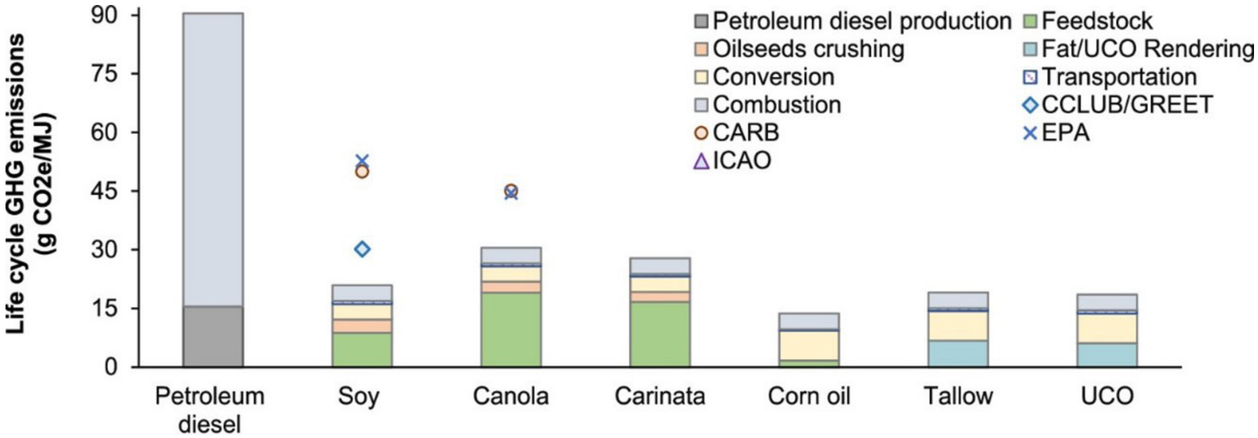


Figure A2: Carbon intensity of biodiesel based on feedstock compared to petroleum diesel [74].

As plants grow, they absorb carbon dioxide through photosynthesis, using sunlight to convert carbon dioxide and water into simple sugars and oils within the plant. During soybean growth, the removal of atmospheric carbon dioxide occurs. This carbon dioxide stored in the plant is then released into the atmosphere during combustion. The cycle would be carbon neutral if only growing feedstock and biodiesel combustion were considered. Emissions associated with production, transportation, and distribution result in net carbon emissions. The average B100 biodiesel blend has 74% lower emissions than petroleum diesel throughout its lifecycle. See Figure A3 below for a visual representation of the life cycle of biodiesel carbon use.

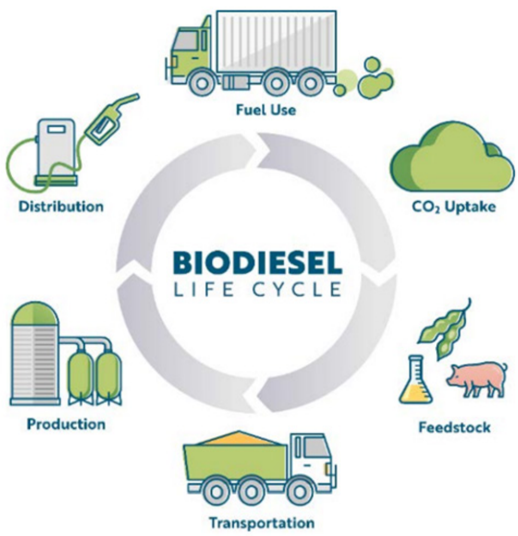


Figure A3: Biodiesel carbon lifecycle, from feedstock carbon capture before production to the use/ combustion of biodiesel [73].

CSL Case Study

Canada Steamship Lines (CSL) carried out a successful biodiesel trial as a decarbonization solution for existing ships [75]. This pilot biodiesel program has been ongoing since 2021. Over these four years, biodiesel usage has mitigated 120,000 tons of CO2 from CSL ships [76]. This demonstration shows that biodiesel is ready for marine deployment, without modifications to large Great Lakes vessels. One benefit Canada has over most of the Great Lake States is a tax incentive for users of biodiesel, making the fuel cost competitive to petroleum diesel or other heavy fuel oils used in the vessels of Canadian fleets.

Figure A4: This is an image of a CSL vessel operating fully on biodiesel [75].

Biodiesel in Michigan

Biodiesel is uniquely situated in Michigan to benefit both the economy and the environment. As most biodiesel in the U.S. uses soybeans as feedstock, the agricultural industry is a key player in increasing the supply of biodiesel available for purchase. Biodiesel contributes $117 million to Michigan's economy, not counting the increased revenue for local farms [4b]. At the state's two biodiesel production facilities, 15 million gallons are currently produced, well under the capacity to grow and produce biodiesel to power the diesel used in the state. As demand for biodiesel increases in the region, likely the production will expand across the state. The Michigan House Bill 4847 proposes to add tax credits to fuel dealers and biodiesel producers to incentives biodiesel production and increase its cost competitiveness with petroleum diesel [76].

Biodiesel can lead to increased engine performance as it has a higher cetane value, which leads to smoother engine operation and increased lubricity [76]. Additionally, filters are changed less frequently, as biodiesel emits fewer pollutants than petroleum diesel. Biodiesel blends of up to 20% are approved by most vehicle manufacturers.

Additionally, there are beneficial impacts on health when petroleum diesel is swapped out for biodiesel. Harmful pollutants, like particulate matter and others, are emitted due to diesel combustion. Biodiesel reduces these levels of pollutants that lead to respiratory and other health issues. It is a non-toxic substance that is biodegradable, unlike fossil fuels [76].

Appendix B: Emissions Reduction Strategy: Electrification and Detroit's Grid

Electrification

Figure A5: *Icon of a dump truck.*

Electrification is a zero-emission technology that can work to reduce local air pollutants. The greatest carbon reduction is found when powered by renewable generated electricity. Co-benefits of electrification include lower running costs, less noise and vibration, improved air quality, and of course, reduced carbon emissions. A broader argument around embodied carbon emissions in battery electric equipment due to the lithium-ion batteries only focuses on one part of lifecycle analysis. Indeed, the embodied carbon of electric equipment is roughly double that of the respective fossil fuel equipment (due primarily to the batteries). The reduced 'in use' emissions more than compensate for this. Lifecycle analysis from Scania shows embodied emissions of 27.5 tCO_2e from a total of 475 tCO_2e for the whole lifecycle of a semi-truck [45]. This compares to the embodied emissions of 53.6 tCO_2e from a total of 255 tCO_2e for grid electricity, or a total of 65 tCO_2e when using renewable electricity. These totals include embodied carbon of all materials, including the battery for EVs. Including the additional embodied carbon of the battery, lifecycle emissions for an EV powered by grid electricity represent a reduction of 46% when compared to diesel trucks. Carbon reduction of 86% is achieved when using renewable electricity in battery electric trucks.

Electrification for large bulk cargo vessels is challenging, as the battery required for large cargo ships are heavy and take up more space than the equivalent diesel tank. Shore power is being considered for cruise ships docking at the Port Authority, but this has its own challenges with cost and electrical capacity. Another consideration that the Port Authority will investigate in the coming years is a portable shore power barge used to power vessels while unloading at terminal docks.

More feasible is the electrification of smaller vessels in the Port region, as the power demand can suit the energy density of Li-ion batteries without impacting operations. The Detroit Princess is a dinner vessel that passengers voyage on for a few hours. The two 750 horse-power engines have the potential to be converted to electric from the current diesel-powered ones. Similarly, the Diamond Jack is a tour boat that takes passengers up and down the Detroit River. A few law enforcement entities on the Detroit River have small vessels that operate on the waterways. These smaller passenger boats are good applications of the electrification of boats, with technology in development that will soon be market-ready and available at a comparable cost.

Goods handling equipment varies based on the operational needs of each of the terminal operators in the Port of Detroit Region. Many of the ships that deliver goods in the Port are equipped with unloading equipment on board – including cranes, pumps, and conveyors – which are powered by the ship engine or auxiliary diesel generators. Once unloaded, goods like aggregates, coal, coke, or heavy goods are moved by forklifts, wheel loaders, and cranes that are powered by diesel engines. Transitioning to electric equipment over the next 5-10 years will be pursued as manufacturers develop battery electric-powered equipment at affordable prices.

Some items, like pumps and conveyors, are already electric powered. Others including cranes, forklifts, and other smaller pieces of equipment have viable electric options on the market today. Wheel loaders and other heavy-duty off-road vehicles are more challenging to electrify as this larger equipment is not yet scalable to the size required by bulk handlers in the Port of Detroit region. Some suitable products are becoming available on the European market and are likely to be made available to the U.S. market in a few years.

Electrification is a viable option for both trucks and rail. There are many market-ready applications of electric trucks and locomotives. Swapping out diesel-powered engines for electric ones results immediately in zero on-site carbon emissions. The greatest impact would result from retiring old diesel engines first as they have older engines that emit more carbon per mile traveled than newer diesel engines. There are challenges including limited range and the need for more robust electric and charging infrastructure. Short-range trucks that remain on-site or travel short distances within Wayne County are likely the best suited for electrification today. As electric drayage equipment increases in range and becomes more feasible for all port operations, diesel equipment should be phased out to reduce emissions. The combination of electrification and purchasing renewable energy will greatly reduce carbon emissions associated with goods handling equipment.

DTE's Grid and Electrification Plans

DTE is the exclusive utility operating in Detroit. The ability of the Port of Detroit region to decarbonize is heavily dependent on DTE's ability to decarbonize the grid within a time frame to match the Port's targets. DTE has mapped a plan to develop 15GW of renewable energy by 2042, where the mix of energy generation is 62% renewable, 6% storage, 20% natural gas, and 12% nuclear [26]. However, a law enacted in 2023 requires utilities in the state of Michigan to generate 60% of their energy from clean sources by 2030, and 100% by 2040 [46]. The state of Michigan is taking aggressive action to reduce emissions due to energy generation, and it will likely push DTE to invest in renewable energy infrastructure more rapidly than currently planned. The discrepancy between DTE's current plan to net zero and the new statutory mandate creates some ambiguity around how Detroit's electrical grid will reach net zero by the year 2040. Decarbonization of the Port of Detroit region in part is dependent on DTE's ability to generate zero emission electricity.

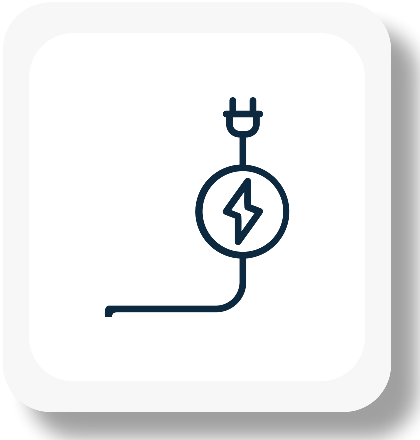


Figure A6: *Icon for electrification.*

Emissions are not completely erased with the swap for electric equipment: using a clean and low-carbon power source will ensure that efforts to electrify reduce overall emissions. DTE has a program called MI Green Power [30] where customers can purchase up to 100% renewable energy by 2027. DTE has stated that more businesses will be able to purchase renewable energy by 2027 through their program, which is Green-e® Energy certified, meaning DTE undergoes biannual reviews to uphold advertising claims and strict accounting to prevent double counting [47], [48].

The cost of renewable electricity purchased through DTE is listed as $0.0034 per kWh, in addition to standard rates [47]. The true cost of decarbonizing the electricity grid is complex. Land-based wind energy is the cheapest form of electricity. Therefore, incorporating wind energy could reduce bills. To fully decarbonize, balancing the electricity grid will be needed, increasing the need for capital infrastructure. However, financial systems in place already spread the cost of new power generating technology developed over a number of years. Cost estimates from government agencies and academics vary widely due to the uncertainties involved around legislation, availability of permits, and global markets for commodities such as steel. Ultimately, the energy transition will require investment, though it is currently unclear how this will be funded in its entirety.

Electricity Recommendations: Efficiency and Renewable Energy

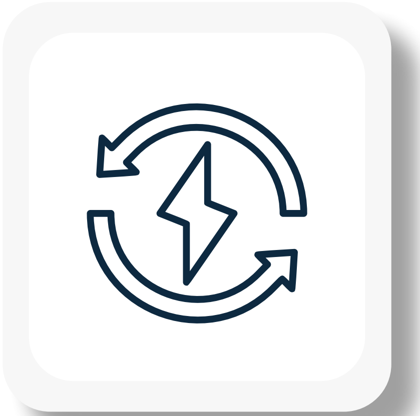


Figure A7: *Icon of renewable energy.*

All of the terminals have some level of electricity use for their administrative functions. While this is better than using coal or natural gas, the DTE electrical grid was at 68.58% generated from coal and natural gas for the 2022 baseline year [20]. Thus, a 'typical' small office (10 people) that uses approximately 10,791 kWh of electricity each year generates emissions of approximately 5.9 metric tons of CO_2e per year, based on the current generation mix of DTE's power grid. DTE has proposed to shift to 26% renewable energy by 2027 [39]. In the meantime, Terminal operators can pay less than one cent per kWh to have zero emission electricity today. This act of purchasing renewably generated electricity reduces administrative footprint by up to 96.7%. For an average small office of 10 people, the carbon footprint would drop to just 0.19 metric tons of CO_2e annually for electricity. To put this into perspective, this is equivalent to saving combustion from 6,439 pounds of coal.

Improving energy efficiency through LED lighting, timers on items left on standby, reducing the use of air conditioners and other similar measures reduces electricity consumption, carbon emissions, and costs for businesses.

Appendix C: Emissions Reduction Strategy: Low-Carbon Shipping Fuels

Green Ammonia

Some researchers have recommended Ammonia (NH_3) as a replacement for diesel fuel to power ships for long journeys across the ocean because it has greater fuel density compared to batteries and hydrogen. This would allow for less fuel on board to power a ship as compared to fossil fuels and leave more space for cargo. Ammonia, to be carbon neutral, would need to be created from green hydrogen as a low-carbon feedstock. Ammonia, while a potential alternative, has challenges associated with it including higher NO emission and efficiency losses in production.

There have been successful examples of the use of Ammonia. A ship, the Fortesque Green Pioneer, used ammonia for a 10-day trial in 2024 in Singapore [49]. It is important to note this was in combination with diesel and biofuel to supplement.

Methanol

Green methanol (CH_3OH) can be synthesized using either industrial methods, using carbon dioxide, hydrogen, and renewable electricity (e-methanol) or from biomass feedstocks (bio-methanol). In one method to produce bio-methanol, biomass undergoes gasification (high temperatures and pressures) with methanol being siphoned off and captured. Green methanol requires renewable electricity and produces very low-carbon emissions. Internationally, methanol is already being used as a shipping fuel. Methanol also has clear advantages in air quality reduction, in terms of particulate matter, sulfur oxides and nitrogen oxides. By having two distinct production pathways, either using electricity to convert CO_2 and hydrogen or gasification of biomass, the underlying technology developed makes it likely that a low-carbon pathway will be used for methanol production. Methanol does have the distinct advantage that it is already used in the shipping industry, and its popularity is increasing. The main challenge is the same as the other low-carbon fuels face: cost competitiveness.

Outlook on Future Fuels

Both these fuels require green hydrogen as a feedstock, which is made by electrolysis (which requires renewable electricity) to split water into hydrogen and oxygen. Enabling efficient electrolysis is key to unlocking other low-carbon fuels, such as green methanol or green ammonia. Fuels requiring green electricity are being synthesized rather than modified, requiring energy input to create the fuel molecules. This, with the additional complexity, leads to higher prices.

Green methanol is further ahead of ammonia in terms of implementation, due to technology readiness and fuel costs, but time and scalability of technology will tell how much of a role either of these fuels will have in the maritime industry.

Appendix D: Decarbonization's Impact on Air Quality

Biofuels Impact on Air Quality

Biodiesel is compatible with current diesel engines, requiring no equipment change, and has an overall positive impact on the reduction of harmful air pollutants. The U.S. EPA performed a comprehensive study on air pollution emissions associated with burning different blends of biodiesel [50] in partnership with the U.S. Department of Energy [29].

Biodiesel has a significant impact, reducing particulate matter by nearly half if a B100 blend of biodiesel is used; however early studies show a likely slight increase in nitrous oxide. There are lower hydrocarbon and carbon monoxide emissions from biodiesel than mineral diesel. Sulfur oxide emissions do not change, as the legal fuel standards are the same for mineral diesel and biodiesel. The consensus is that overall air quality from a health perspective is much better, as the PM, CO, and HC reductions far outweigh the small increase in NO_x. This potential increase in nitrous oxides can be mitigated by adjusting the timing of the fuel entering the engine as well as adding exhaust gas recirculation (EGR) systems [51]. Additionally, using selective catalytic reduction (SCR) technology in engines breaks down NO_x [52]. These technologies are often utilized in current diesel engines, so ensuring these procedures are followed will mitigate any potential increase in NO_x. The overall air quality will be improved when mineral diesel is replaced with biodiesel.

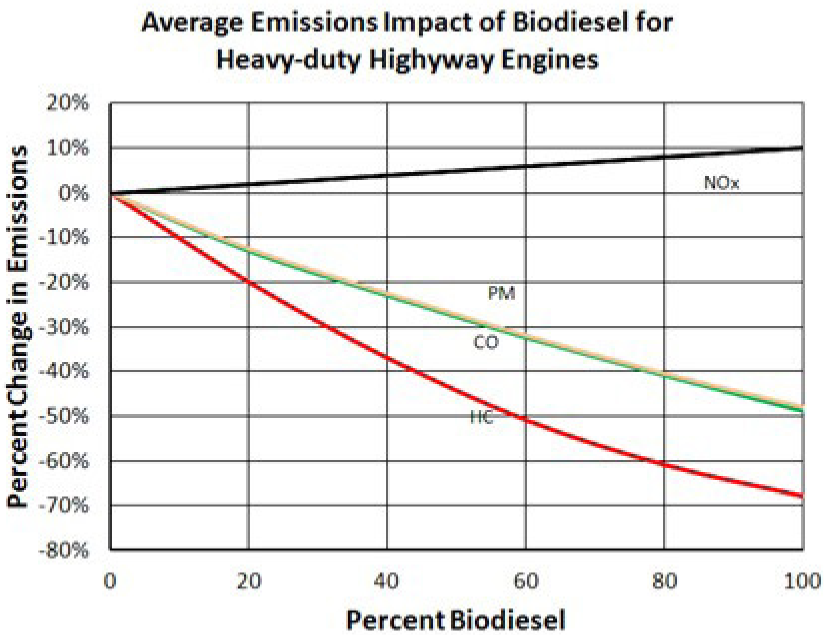


Figure A8: *Graph comparing air quality metrics with the percentage of biodiesel blends [23].*

Low-Carbon Alternative Fuels Impact on Air Quality

In the slightly longer term, switching equipment to be powered by low-carbon fuels would have significant reductions in harmful air pollutants. Technology is being developed to power ships, heavy equipment, and trucks with the likes of green methanol, ammonia, and hydrogen. Currently, all three could be viable options, and the one that proves to be the most cost-effective to produce at scale will win out as the future fuel of shipping. All these options have large emissions reductions of harmful air pollutants and carbon emissions.

Assuming green methanol as the fuel of choice for these companies, emission reductions of PM and SO_x by up to 95%, and NO_x reductions of up to 80% would be seen [53], [54]. Ammonium has similar air pollution reduction percentages. If hydrogen is used to replace diesel fuels in the port region, emissions will be greatly reduced. Hydrogen emits zero sulfur oxides, carbon monoxide, heavy metals, or hydrocarbons. NO_x can be formed in the combustion of hydrogen, but with engine controls the amount created will be minimal compared with diesel. If hydrogen fuel cells are used, there will be zero emissions associated with powering engines [55].

Cost-Benefits of Improved Air Quality

This report has previously highlighted the high prevalence of asthma and other health outcomes associated with poor air quality in Southwest Detroit. The physical harm, including shortened lifespans for people affected by pollution, is tragic and its impact cannot be easily measured, and should not be minimized. Often not considered in this is the negative financial impact of poor air quality on residents and the city. Chronic exposure to harmful air pollution leads to increased costs for a region due to increased hospitalization and healthcare needs, as well as loss of productivity of workers. There are clear costs associated with health impacts, from hospital treatment and days off work. Healthcare costs of poor air quality in the U.S. caused by burning fossil fuels in 2018 were estimated to be **$2.9 trillion** according to the Center for Research on Energy and Clean Air [56]. Implementing carbon reduction measures also reduces harmful air pollution. To reduce the healthcare and other costs associated with negative health impacts from poor air quality, reducing fossil fuel combustion is essential. Since the implementation of the Clean Air Act (CAA) in 1970, the U.S. has spent $65 billion per year to ensure the CAA standards are met. The most recent report to assess the cost and benefits of these practices to improve air quality shows that the $65 billion investment directly led to $2 trillion in benefits in 2020 [57]. The EPA estimates for every $1 spent on air quality improvement, $3 is saved in avoided medical expenses, enhanced quality of life, and reduced sick days [58].

Overall, air pollution negatively impacts health, with residents, employees, hospitals, and communities disproportionately bear these costs. There is a clear overall net benefit in terms of the financial impact due to improved air quality, with implementation costs of technologies that improve air quality a small price to pay in comparison with the overall reduction in healthcare and associated costs.

Appendix E: Emissions from Office Administrative Functions and Commuting

Commuting Emissions: Methodology and Results

A typical commute may consist of a large gas-powered vehicle traveling 20 miles one way, every working day for a year. This equates to approximately 3.13 tons of CO_2e per year per employee. Switching to a comparable electric vehicle charged using Detroit's power grid can cut these emissions by about 48%, saving 1.5 tons of CO_2 equivalent annually. This is equivalent to driving 4,204 fewer miles in a regular gas car. Further, if the EV is charged using a cleaner, more renewable power grid, emissions could drop by up to 98.3%, similar to driving 8,611 fewer miles in a gas car each year.

While this does not apply to all jobs, some employees are able to work from home. Emissions from home working are far lower than the average commute. Alternative means of travel, such as carpooling, taking public transit, or active travel options all have reduced emissions compared to a gas-powered car if office commuting is necessary.

Utility Emissions: Methodology and Results

The most accurate method for calculating emissions from utilities, including electricity and natural gas use, would be to obtain utility bills from the administrative offices in the Port of Detroit region. Where possible, electricity and natural gas usage was provided. Otherwise, the methodology from the U.S. Energy Information Administration (EIA) [59] and supported by the Energy Star [60] was used to calculate electricity and natural gas use based on the size and type of building. Below is the methodology used to calculate these emissions.

1. Determine the building type and size (square footage).
2. Find the average Energy Use Intensity (EUI) based on building type (kBTU/sq. ft./year)
3. Determine the breakdown of the EUI between electricity and natural gas use in Michigan.
4. Calculate the actual energy use (Actual Energy Use = Square Footage x EUI)
5. Convert the energy use (kBTU) to electricity use (kWh) and natural gas use (ccf).
6. Calculate emissions based on the total electricity and gas usage using EPA emission factors.

The utility carbon emissions detailed in this report at each terminal are estimates of energy usage. The City of Detroit passed the Benchmarking Ordinance in 2023, making it a requirement to submit water and energy information to the city for buildings over 25,000 square feet.

The overall emissions for the Port of Detroit operation's administrative facilities utilities for the baseline year of 2022 totaled 1,237 tCO_2. Electricity use was 1,121 tCO_2 and natural gas use was 116 tCO_2. These emissions are relatively small in comparison to the emissions as a result of direct port activity.

Port Wide Commuting and Utility Emissions

It is important to note a few key assumptions from these calculations in the table below. It is assumed that 10% of staff at Cleveland Cliffs work on Port activities, as we were unable to identify which portion of their operations house maritime administration. Levy participates in DTE's MI Green Power to purchase 100% renewable electricity to power their port operations.

Terminal Name	Electricity Emissions (tCO_2e/yr)	Natural Gas Emissions (tCO_2e/yr)	Commuting Emissions (tCO_2e/yr)	Administrative Emissions tCO_2e/yr)
AJAX Paving Company	67.9	12.0	21.9	**101.8**
Cleveland Cliffs	69.0	12.2	403.8	**485.0**
Carmeuse Lime	13.3	2.3	31.3	**46.9**
Detroit Harbor Master / Sherriff Dept	3.2	0.6	15.7	**19.5**
Detroit Princess	201.0	0.0	27.2	**228.3**
Detroit Salt Co.	15.2	2.7	15.7	**33.6**
Detroit Wayne County Port Authority	270.5	0.0	30.3	**300.7**
DTE Zug Island Operations (EES Coke Battery)	54.1	9.6	87.6	**151.3**
Gaelic Tugboat and Diamond Jack's River Tours	10.6	1.9	15.7	**28.1**
Great Lakes Towing	31.6	5.6	15.7	**52.9**
Holcim/LaFarge Detroit Cement Terminal	130.2	23.0	37.6	**190.8**
Hollingshead Materials, LLC/ SRM Concrete / Smyrna	5.1	0.9	15.7	**21.6**
J.W Westcott Co.	8.6	1.5	12.5	**22.6**
Levy	0.4	0.6	12.5	**13.5**
Superior Materials (owned by Levy)	4.8	0.8	12.5	**18.2**
Marathon Oil Co.	9.6	1.7	15.7	**26.9**
Marine Pollution Control	13.3	2.4	18.8	**34.5**
Michigan Marine Terminal	8.0	2.2	12.5	**22.7**
Nicholson Terminal and Dock Company (Ecorse Location)	26.0	4.6	12.5	**43.2**
Nicholson Terminal and Dock Company (Jefferson Location)	12.8	2.3	12.5	**27.6**
St Mary's Cement (Votorantim/Cimentos)	84.1	14.9	31.3	**130.3**
US Army Corp of Engineers	4.3	0.8	9.4	**14.4**
US Coastguard	74.2	13.1	125.2	**212.5**
Waterfront Petroleum	2.9	0.5	37.6	**41.0**
Total Emissions	**1,120.7**	**116.2**	**1,030.9**	**2,267.8**

Table A1: *Estimated emissions from administrative functions (office) for electric and gas utilities and commuting. Estimates are based on office and number of employees.*

Heating Recommendations: Upgrade from a Gas Furnace to an Air Source Heat Pump

Across Southeast Michigan, the main source of energy for space and water heating is natural gas furnaces and hot water heaters. In a case where a 60 kW office gas boiler (for a 10 person office) in Detroit is swapped out for a 16 kW air-to-water heat pump (lower power requirement due to 300% - 400% efficiency gain in heat pumps), there's an expected drop in emissions by 19.7% (using grid energy). Swapping from a gas furnace to an air source heat pump would save approximately 4.5 metric tons of CO_2e per year, which is similar to the emissions from driving an average gasoline-powered passenger car for 11,536 miles. When using renewable electricity, emissions savings will be 21 metric tons per year (approximately 90% emissions savings).

If retrofitting with an air source heat pump is not viable, purchasing renewable natural gas (RNG) would heavily reduce emissions [61]. Renewable natural gas is created from the anaerobic digestion of waste, such as food waste, animal manure and wastewater treatment plants. DTE offers a program called Natural Gas Balance which offers tree planting to offset emissions and an investment in additional renewable natural gas supply [62]. The program does not state what percentage of the bill is from carbon reduction (from RNG generation) or directly offset.

Insulation and draft proofing offer good returns on reduced heating and cooling costs. Retrofitting internal, cavity wall, external, and attic insulation provides many options for healthier buildings, and typically have payback periods of 2.5 years [63].

Figure A9: *Heat pump and solar collector on roof of a building.*

Appendix F: The Role of Offsetting

Carbon offsetting is the practice of investing in projects which either sequester carbon emissions (for example, tree planting), or prevent emissions that would arise without project funding (for example renewable energy projects where otherwise unaffordable). Offsetting has been a source of controversy; however, the Intergovernmental Panel on Climate Change (IPCC) has included offsetting in all models which limits warming to <2 degrees Celsius or lower by 2100 [64]. It is one of many tools in the toolbox for tackling climate change and omitting offsets will need deeper action elsewhere to stay on track.

Figure A10: *Tree planting to offset.*

The Oxford Principles for Net Zero Aligned Carbon Offsetting [65] provides guidelines to help organizations achieve their net zero plans in a responsible and feasible way. There is no fixed percentage to define residual, or difficult to eliminate emissions, therefore this guidance aids decision making across different sectors. There are four principles to use as guidance for carbon offsetting, which are detailed throughout this section.

1. Cut direct and indirect emissions, ensure the environmental integrity of carbon credits purchased, and maintain high transparency around emissions and reduction planning.
2. Choose carbon removal offsets rather than avoided emissions offsets.
3. Prioritize removal of CO_2 that have a low risk of reversal.
4. Support innovative approaches for achieving net zero.

The Port of Detroit Decarbonization Plan by necessity will include offsetting. Companies with ambitions to reach net zero need to reduce their carbon emissions as far as practicably possible, then only use offsetting to remove residual emissions to reach net zero. Even the most sustainably minded companies will still have some greenhouse gas emissions remaining after the implementation of feasible reduction strategies, therefore offsets are necessary to reach net zero. The focus must be on reducing carbon emissions, rather than offsetting. The criticisms of offsetting are mainly around the shift of focus from decarbonization, and the idea that paying to offset solves humanity's challenges of addressing climate change. Offsetting is reasonable for low levels of emissions, however, without rapid and thorough action to decarbonize, climate change will remain a threat to the human and natural world.

The Port Authority, in partnership with community organizations, is working to plant trees throughout the port region, to serve as an immediate carbon reduction strategy and to improve biodiversity. In the context of Southwest Detroit, offsetting from planting trees will not improve local air quality as air pollutants are not removed by vegetation. Offsetting projects can, however, have positive co-benefits, including increased biodiversity, sound barriers, or improved quality of life. Tunley recommends using a certified provider, where offsetting projects are regularly audited by a third party.

Following the implementation of all feasible carbon reduction methods and technology, offsetting is a necessary tool to reach net zero emissions. Offsetting should be encouraged when opportunities arise, rather than waiting for all carbon reduction strategies to be implemented. Ensuring the principles for offsetting are followed will give the Port increased confidence in responsible offsetting practice [65]. The maritime industry has such large equipment and heavy carbon fuel sources that it will be challenging to get to zero emissions through technology upgrades alone by 2040, thus offsetting will be needed to reach net zero emissions.

Appendix G: Electrification Cost-Benefit Analysis

Electrification has many co-benefits such as lower running costs, reduced noise and vibration, and improved air quality. In general, capital costs are higher (largely due to the battery), while operating costs are much lower. Equipment with established electric alternatives typically only have a slightly higher cost to purchase/lease. Heavier equipment, or electric equipment new to the market will be significantly more expensive to purchase than diesel equipment. Payback times will be longer for large equipment (such as heavy-duty wheel loaders, or electric semi-trucks), and in some instances, more expensive. However, with grants available to address capital costs, operators can take advantage of reduced operational costs. For an annual mileage of 100,000 miles, diesel consumption would be approximately 14,300 gallons (7 MPG), costing approximately $47,200 per year at $3.30 per gallon. Electricity demand for a Tesla semi would be approximately 200,000 kWh to cover 100,000 miles. Paying $0.12 per kWh would cost approximately $24,000 per year, around half the cost of diesel.

Small Equipment

As an example of smaller, more established equipment, a diesel forklift truck with a 10,000 lbs. carrying capacity has a 10-year lifecycle cost of $175K, compared to only $96K for an electric equivalent. The capital cost is $10K more for the electric model; however, this is offset by the cost differential between diesel and electricity. An online calculator can provide estimated lifecycle costs at the **Electric Power Research Institute** [66].

Figure A11: *Electric forklift.*

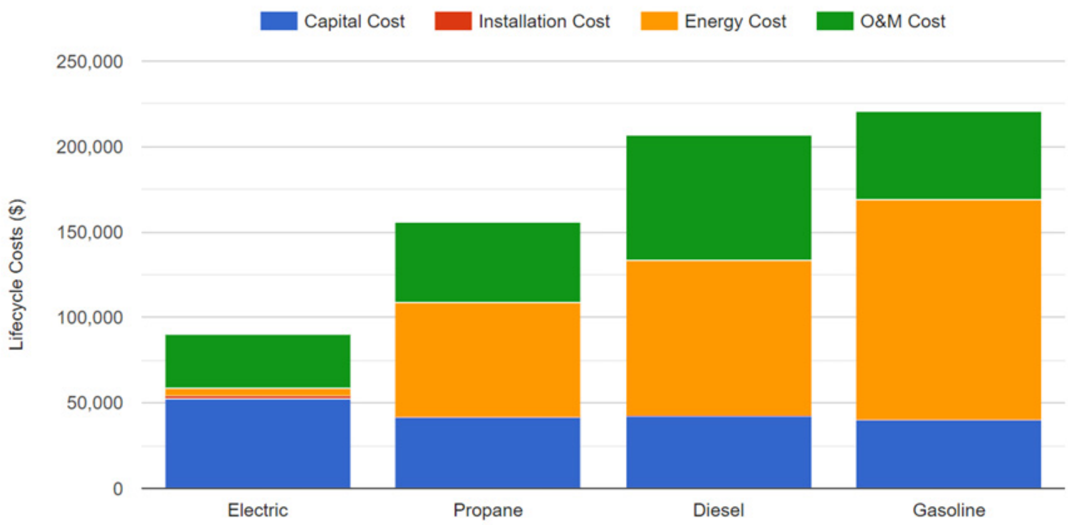


Figure A12: *Bar graph showing lifecycle costs of forklift trucks with 10,000 lbs carrying capacity [66].*

This example of an electric forklift is well understood, and technology is implementable and affordable today. Performing a cost benefit analysis on large equipment is more challenging, due to:

- Price obscurity – each model purchase is negotiated.
- New to the market – little is known about performance.
- Longevity – estimated/projected, rather than known.

Large Equipment and Trucks

Figure A13: *Electric wheel loader*

Electric equipment has a higher purchase cost, primarily due to the battery, and secondly, the R&D costs associated with bringing new technology to the market before supply chains are matured. These capital costs are typically outweighed by the lower running costs for operators over the lifetime of the equipment and can be expressed in a payback time (the year when cumulative fuel savings pay for the initial investment difference). The optimum case for current electric technology is for small equipment (see the above example of a forklift) with a medium to low power requirement. Further, electric forklift trucks have well established supply chains [66]. The current advice for operators is to seek grant funding to pay at least a portion of the capital costs. Governments are incentivized to subsidize electric equipment due to the reduced health burden of lower emissions of criteria pollutants.

A medium sized electric material handler has an estimated payback period of 18 months, after which the lower running costs will save the business money on an ongoing basis [67]. Medium sized electric trucks can have payback periods as short as of 3-5 years (depending on usage) [68]. However, less frequently used equipment could take longer to see a financial payback [69]. Class 8 trucks require much larger high-capacity batteries and are the most challenging to compete with diesel equivalents [70].

To establish a comparative total cost of ownership of electric versus diesel buses, Buffalo State University commissioned a study in 2021 [71]. This example is indicative of other large equipment at ports with similar battery capacities and market maturity. By far, the greatest expense of electric equipment is the upfront capital cost of purchasing. However, electricity is a much cheaper power source when compared to diesel. Maintenance costs are also much lower over the lifetime of an electric vehicle, approximately half of the cost to properly maintain a diesel equivalent machine. On the whole, electric equipment is anticipated to have similar costs over the lifetime, largely influenced by capital cost. The large upfront costs are a hurdle to businesses, that can potentially be overcome with grant funding. Further, capital costs for heavy electric equipment are predicted to fall as the market develops and matures.

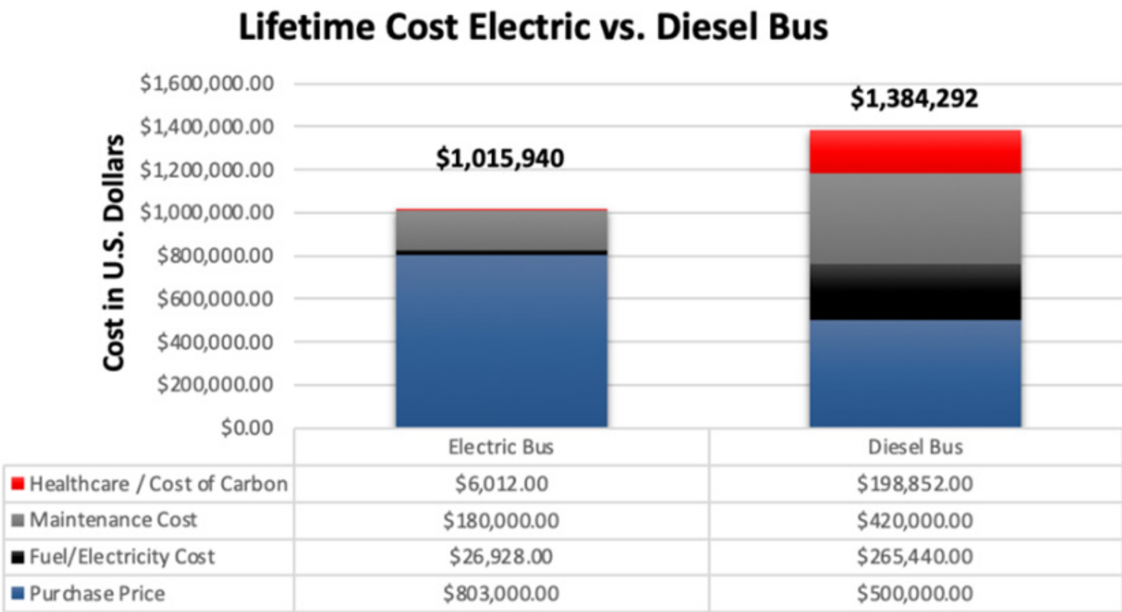


Figure A14: *Cost-Benefit Analysis of a New York bus company's conversion of diesel buses in their fleet to battery electric [71].*

Further Outlook

There are signs in the market that point to the case for electrification of diesel equipment. One example is the price of batteries for electric equipment. As historically one of the more expensive pieces of an electric vehicle, the cost of a lithium-ion battery has come down significantly in the last decade. Below depicts how the cost of the average battery has shrunk over the last 12 years.

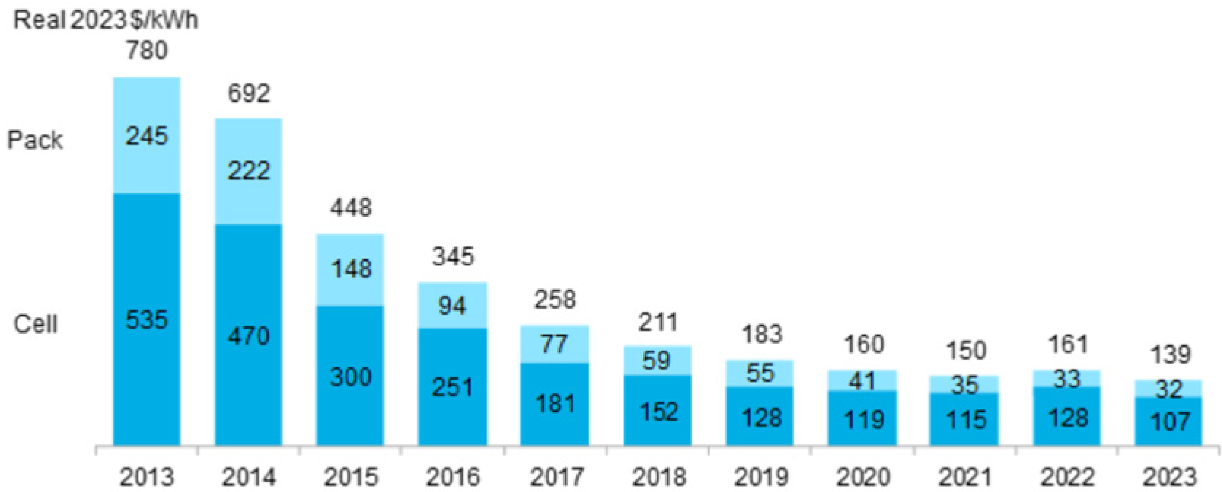


Figure A15: *Battery costs in dollars per kWh by year [72]*

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